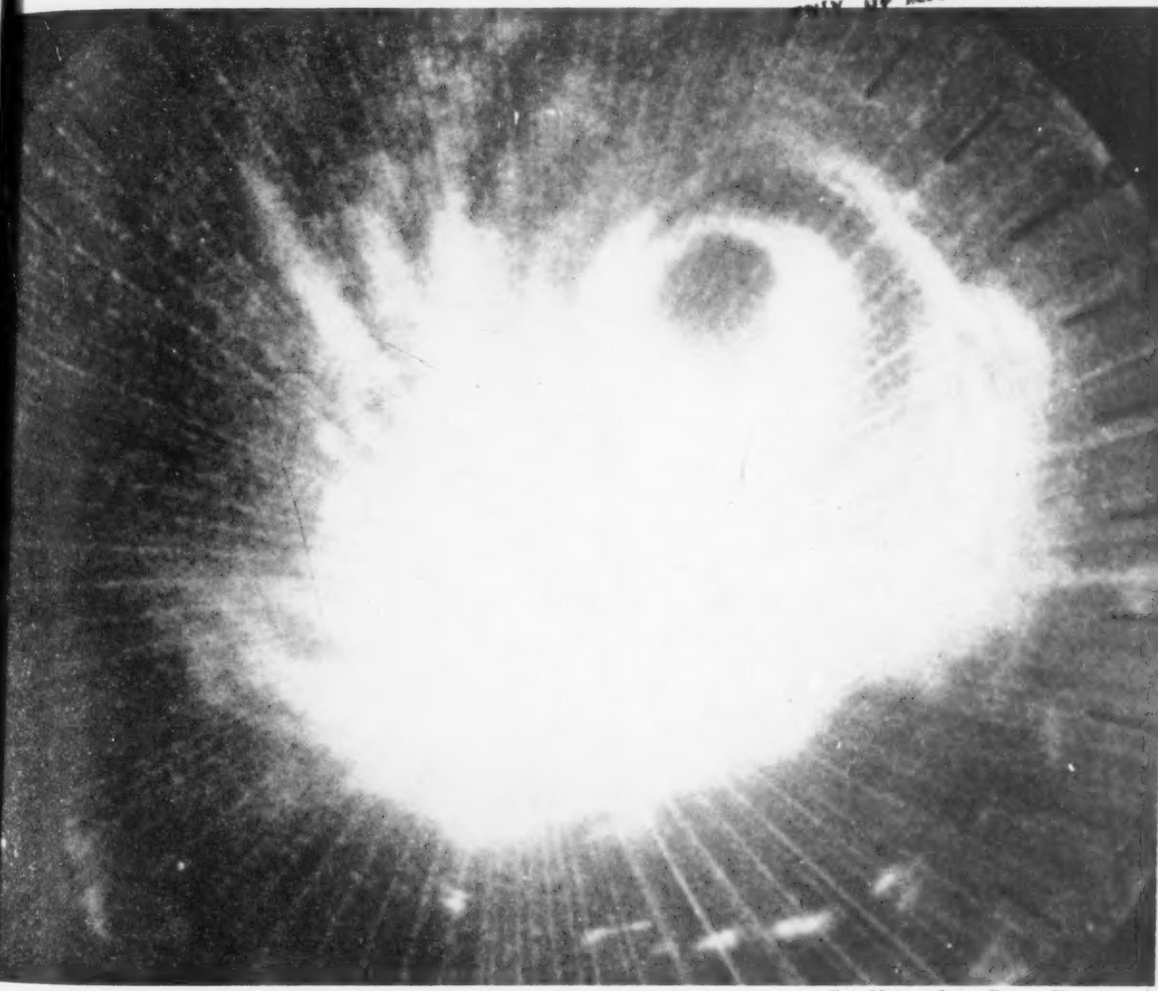
The SCIENTIFIC MONTHLY

DECEMBER 1946



See *Meteorology Grows Up*, page 4

Radar Portrait of a Typhoon

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DECEMBER 1946

METEOROLOGY GROWS UP

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METEOROLOGY is a young science. For millennia the mariner cast his weather eye upward, forecasting a rainy day because he remembered

> If red the sun begin his race
> Be sure the rain will fall apace.

To advance to the weather forecast of 1946, in which amount and height of cloud levels, upper-air as well as surface winds, temperatures, hydrometeors, and times of incidence and cessation of precipitation are given, required the development, among other things, of a rapid method of communication. During the nineteenth century, telegraphy provided that method. Meteorology was born.

From then until the outbreak of World War II, weather science was very much an infant. Only in the twentieth century were the principles of air mass and frontal analysis evolved. In degree of fundamentality, this is comparable to the development of Dalton's Atomic Theory for the chemist or Newton's Laws of Motion for the physicist. Before the Nazi march into Poland, meteorology had advanced no farther than had chemistry in the early nineteenth century and physics in the early eighteenth.

Then came the war—modern, scientific, more deadly than any before. It was a physicist's war. Great scientific demands were made of meteorology, demands more taxing than should be put upon an embryo science. Meteorology rose to the occasion, grew, and managed to fulfill many of the obligations required of it. The influx of new blood in the form of young chemists, physicists, geologists, engineers, who through the exigencies of war were taken from their chosen occupations, put into uniform, and summarily trained in a new profession, was responsible for this growth to a large extent. Fresh concepts, new knowledge, were so introduced. The civilian establishments—the Weather Bureau and certain large universities—were spurred to new efforts. The impact of electronics was another factor which rushed meteorology to its precocious maturity.

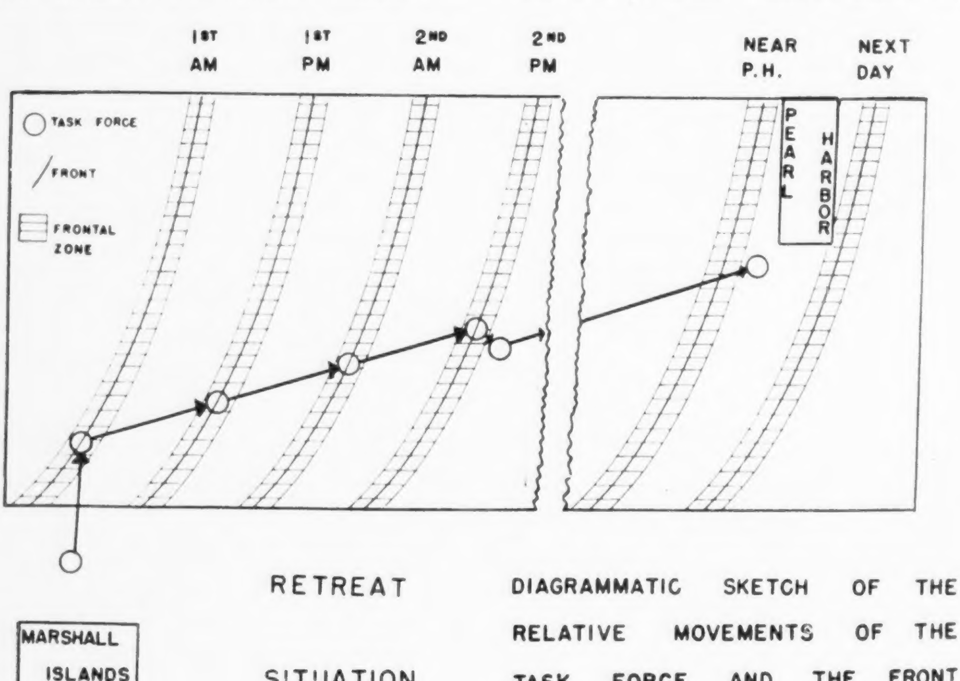
The results of this rapid development are deserving of evaluation. At close range, however, it is impossible to evaluate; one must be content with reporting. It would seem interesting, nevertheless, at this time, to record some of the progress made by meteorology during the past few years. An attempt will be made here to show some of the problems with which meteorology was faced and the techniques developed to supply the solutions to these problems. Finally, a few words will be added to emphasize the need for a complete review of this science which has grown through expediency to dimensions so vast as to be all but unsupportable by the delicate frame of its earlier development.

It should be noted that the writer is in no way compiling a comprehensive history of meteorology. Her experience has been entirely with Naval Aerology—first in the Operational Analysis section and, subsequently, in the Research and Development section of the Office of the Chief of Naval Operations. It is felt, however, that the problems and solutions of Naval Aerology are representative of all of meteorology. This is particularly true because of the high degree of co-operation by the Navy, Army, Weather Bureau, and universities in the prosecution of a large part of the work. Thus, only information contained in the files of the Navy will be presented here.

Navy Requirements of Aerology

Some of the demands made by the Navy of the aerological service can best be ascertained from illustrations. One such case involves the original attack on the Marshall and Gilbert islands—the raid which marked the first offensive action of our naval forces. This took place on January 31, 1942. Two task forces approached these islands, one from the north and the other from the south, subjecting Kwajalein, Maloelap, Wotje, Jaluit, Mili, and Makin atolls to simultaneous air attack. The cloudless sky and unlimited visibility permitted planes from the northern task force to attack the island installations almost continuously. However, during the early afternoon, the Japanese planes made two bombing attacks on the carrier as the last raiding planes were being landed. It was deemed advisable to discontinue offensive operations and withdraw. Considering the superior speed of planes, how would it be possible for the task force to find shelter? The aerological officer aboard the carrier had the answer.

A cold front extended southwestward from a depression centered about 150

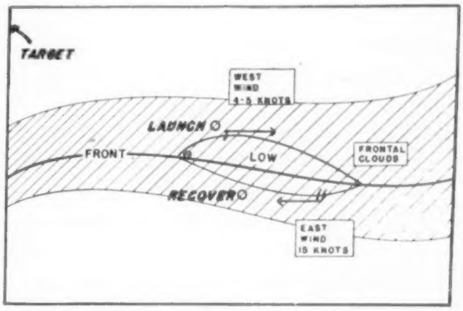


THE FIRST ATTACK ON THE MARSHALL ISLANDS

miles north of Midway. He recognized that a natural smoke screen was oriented in a direction toward Pearl Harbor. It was apparent that by steaming a northerly course at high speed until the frontal zone was reached and then changing to 065° (True), adjusting the speed to that of the front, the force would remain in the protective frontal weather all the way to its base. This tactical maneuver was executed. The front was found in its forecast position with light showers, low ceiling, and reduced visibility over a zone 30 miles wide. By radar, enemy planes were seen searching for the task force, but none was observed visually, and no counterattack materialized. Finally, on the night of February 2, the Task Force Commander decided that the ships were out of range of Japanese patrols. The task force was taken out of the front, and the helmsmen ordered to steer by remaining 30 miles off the line of continuous precipitation and towering cumulus which delineated the frontal zone. A satisfactory landfall at Pearl Harbor was made in this manner.

Another illustration may be taken from one of our attacks on Rabaul. During this discussion it is important to remember that this operation was not scheduled to coincide with favorable weather conditions. Although it was an attack of necessity (to protect our landing on southwestern Bougainville), a weather situation prevailed which required an excellent appraisal of the possibilities inherent in that situation to achieve the maximum benefit from it.

An analysis of the weather map indicated that the intertropical front was situated in the vicinity of the position from which the planes were to be launched. Observations made aboard ship confirmed this weather analysis but suggested as well that a wave disturbance had been formed along the front near the launching point. Reference to the accompanying figure will indicate



ATTACK ON RABAUL

how the wave formation assisted the task force in making a perfect strike against Rabaul. The exceedingly fine conditions for such an operation motivated the comment by the ship's company that "an angel was riding on the yardarm."

The situation may be outlined in the following manner: The task force to the north of the disturbance was able to steam toward Rabaul, heading into the wind while the aircraft took off for their mission. The ships did not have to deviate from their base course during the launching. While the task force remained hidden from enemy scouts under the frontal clouds, the air group found the target, Rabaul, to the west of the disturbance, enjoying unlimited ceiling and visibility—bomber's weather. By the simple maneuver of steaming through the front in order to take a position south of the wave and reversing the base course 180 degrees during the withdrawal, the task force was again able to utilize the head winds in recovering the planes without the loss of any time in leaving the danger zone.

Illustration after illustration could be cited. An aerologist selected the one day out of twenty when weather conditions made possible the landing in North Africa in November 1942. Typhoons were forecast so that the United States forces could dig in and minimize the damage resulting from the big blow; also, so that an offensive group could

attack Japanese positions in the wake of a typhoon before the enemy had the opportunity to prepare for defensive action. This was the case in the attack on Formosa. Sea, swell, and surf were forecast before each amphibious landing. Road conditions, dependent upon weather, were determined and taken into account in the over-all strategic plans. The forecast of the position of the equatorial front in 1943–1944 determined that the Gilbert Islands would be taken in November and the Marshalls in February.

Less dramatic than these tasks of naval aerologists but equally important because of its absolute routineness was the job of forecasting for air logistics. The war in Europe as well as in the Pacific depended to a great extent on air supplies. Every moment of flyable weather had to be flown. If fog with resulting zero-zero conditions was forecast for Stephenville, Newfoundland, by 3:00 P.M., a transport plane on its way to Europe via Stephenville could be cleared for flight only if it could reach that terminal before 3:00. The forecaster could not afford to be wrong. The war situation did not permit him to be over-cautious.

Aerological Progress During the War

It should be noted that the aerological science met most of its obligations. It would be well to determine how this was made possible. Let us review the progress the science made during the war years.

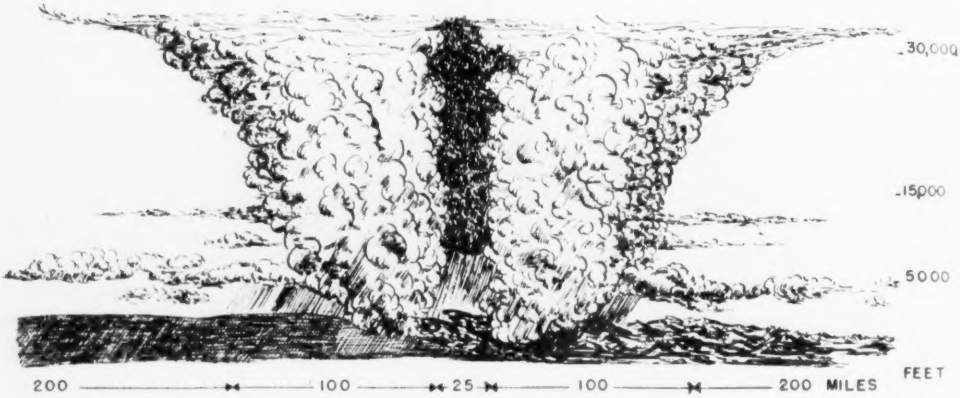
Climatology. Much could be learned by reviewing weather records of the past. Units were established by the Army, Navy, and Weather Bureau to collect and analyze any and all weather data available from the beginning of weather records to the present. Tabulations were made of pressures, temperatures, rainfall, visibilities, cloud heights, wind directions, and velocities for geographical locations all over the world. Often as much as a year before any major action during the war, climatological records were assembled for use by the Joint Chiefs of Staff for tactical and strategic planning. Thus, in September 1944 these units worked day and night to give the requisite data about Okinawa. Not only were the figures given, but summaries were prepared under some of the following headings: Number of days per month suitable for high-altitude bombing, for low-level bombing, and for the use of incendiary bombs; sea and surf conditions by months in accordance with whether the winds were in the northern octant, in the northeastern octant, etc. The probability that a day of rain would be followed by another day of rain was calculated. Every possible interpretation of the data available was made to aid the strategists who planned the progress of the war. Enemy records as well as Allied records were combed for information. Eventually, again as a joint effort of the major activities interested in weather, a project was initiated to put all the available climatological data in the more readily useful form of punch cards. Since weather does not differ too much from year to year, climatology proved a valuable aid in the prosecution of the war.

Long Range Forecasting. A forecaster usually feels a considerable degree of confidence in a forecast extending for 24 hours, and, although confidence decreases somewhat with time, he feels able to prognosticate weather conditions for a period of 36 hours. Beyond that, he may or may not hazard a guess but if he is honest he will label his forecast a guess or use the euphemistic term "outlook." For operational purposes under war conditions, the 36-hour period was frequently insufficient. A major offensive action required greater advance notice of favorable conditions. Troops

and supplies could be held in a state of absolute readiness for attack for only a very limited time. To meet this requirement, the Army, Navy, and the Weather Bureau each created a long-range weather unit. These three units working in close collaboration studied weather patterns and statistical correlations to the end of being able to predict weather for a period of five days. In many cases, their success was outstanding.

Weather Networks. To a great extent the accuracy of a weather forecast is a direct function of the density of the weather-reporting network. With the outbreak of the war, weather units were established in many geographic localities where reports were deemed necessary but had never before been available or at best had been too sparse. The Aleutian Islands and Greenland each got their quota of weather stations. As each Pacific island or atoll was taken, weather units were established. Occasionally, several days before public release of a landing was made, the aerologist learned of the action because a new weather report came in at a latitude and longitude indicating former Japanese-held territory. It almost seemed as though the rainmakers, as the aerologists are called throughout the service, landed with the first assault troops, setting up their anemometers and wind vanes and barometers before the beachheads were well established. When weather reports were required from within enemy-held territory, submarines or PT boats were sneaked into the dangerous waters, returning eventually with the requisite data. Aircraft were also assigned the mission of getting the weather. In cooperation with the Chinese and Russians, American weather stations by the dozens were established on the Asiatic mainland. This was necessary since the normal movement of the weather systems from west to east made knowledge of Asiatic weather vital for operations in the western Pacific. One technique employed, a war development which shows great peacetime potentialities, involved the setting out of automatic weather stations. These are units of either land or buoy construction which contain weather-measuring instruments. The instruments operate a radio according to a fixed schedule. As an automatic weather station goes on the air it gives its call letters in Morse code and then a series of dashes. The first series of dashes indicates atmospheric pressure. A radio operator, perhaps 500 miles away, can count the number of dashes and translate that number into the pressure observed by the barometric element of the automatic weather station. Wind direction and velocity, temperature, and amount of precipitation follow in the same way. These automatic weather stations can operate for a period of three months without any attention. They can be set out in isolated land or ocean areas where it would be impractical to establish and maintain a manned weather unit.

U. S. Navy Photo
AUTOMATIC WEATHER STATION



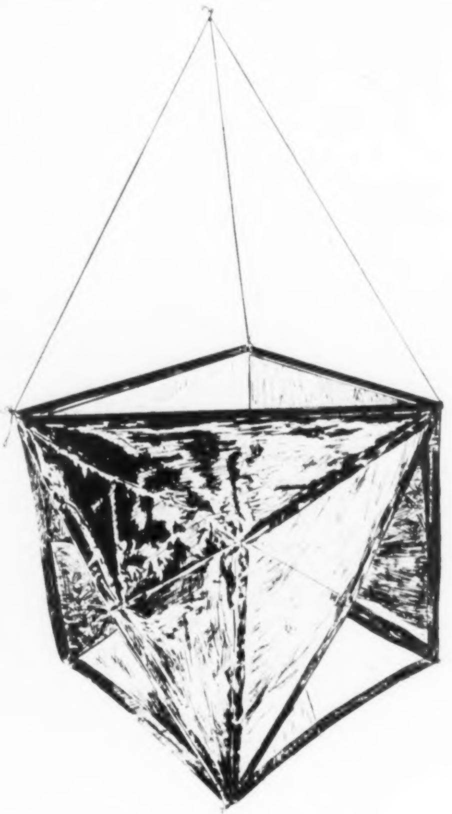
SCHEMATIC CROSS SECTION OF A TYPHOON OR HURRICANE

Another significant development which may possibly be treated under the general heading of weather networks is the matter of hurricane and typhoon reconnaissance squadrons. Before the density of the weather network was so greatly increased it was thought that only a half dozen or so typhoons raged through the Pacific during a year. During the war it was established that some two dozen storms might occur each year. This knowledge resulted entirely from the fact that now typhoons are observed, whereas earlier they went through their life's cycle without detection. With our fleet everywhere, each typhoon was significant. The motion of these cataclysmic tropical storms is usually erratic, however. To determine the course of an individual storm, it is necessary to see it and track it. Aircraft were assigned to the specialized duty of tracking these storms. Weather reconnaissance squadrons were established. A plane, upon hearing the report of an incipient tropical storm, would fly out into the region where it was reported, find it by means of the mammoth clouds associated with it, and then—such is the wonder of aircraft achievement—fly into the center of the storm. These planes would brave the **150**-knot winds which form the circumference of the hurricane or typhoon to get into the calm center, or eye. Once within the eye, they would radio back their position. As long as they remained within the central portion, the position of the huge cyclone was established. Later radar, ship-, land-, or aircraft-based, aided in the tracking.

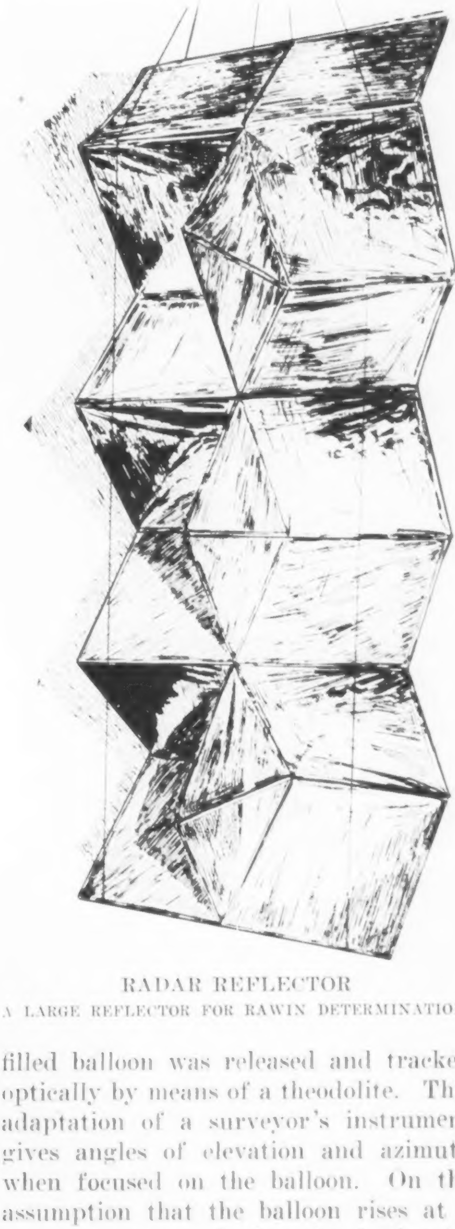
Microseisms. One has but to read a report of the destructive force of a typhoon or hurricane to realize how significant a part one plays in weather. Earlier, mention was made of sending planes to scout for an incipient storm. It was vital that each be detected at the earliest moment. Weather-reporting units on ships or islands found the first signs of some. Others would have escaped notice for several days had not use been made of a fact long known but never before investigated or put to use. A seismograph set up for recording earthquakes always shows minor vibrations even when no quake is known to occur. These are called microseisms. In recent years it was established that microseismic activity resulted from the action of a severe storm on the sea. Moreover, microseisms are directional. A microseismic station can take a bearing on the storm producing the phenomenon. At present the bearing is used in directing a plane in its search for the storm. Eventually, several microseismic stations, each taking bearings, will be able to locate the storm by

finding the intersection of these bearings. Microseismic stations were established both in the Caribbean and in the Pacific. The birth of a hurricane or typhoon did not escape the notice of the pendulum of the microseismograph.

Rawins. It seemed inevitable that radar, which played such a tremendous part throughout the war, would find weather applications. Actually, two great contributions were made to this science by radar techniques. Radar wind soundings—"rawins"—is the first of these. The great pressure systems which determine the weather are steered by the upper air currents. To forecast effectively it is necessary to know wind directions and velocities at 5,000, 10,000, and 20,000 feet. Formerly, a helium-

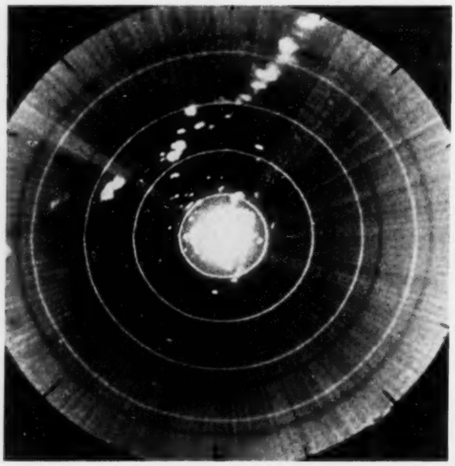


RADAR REFLECTOR
A SMALL REFLECTOR FOR RAWIN DETERMINATION.



RADAR REFLECTOR
A LARGE REFLECTOR FOR RAWIN DETERMINATION.

filled balloon was released and tracked optically by means of a theodolite. This adaptation of a surveyor's instrument gives angles of elevation and azimuth when focused on the balloon. On the assumption that the balloon rises at a constant rate and that its horizontal trajectory is a function of the wind direction and velocity, these can be calculated at any desired altitude in the atmosphere. The difficulty was, of course, that when weather conditions are bad—when there is a low cloud cover—optical tracking is impossible. Need-

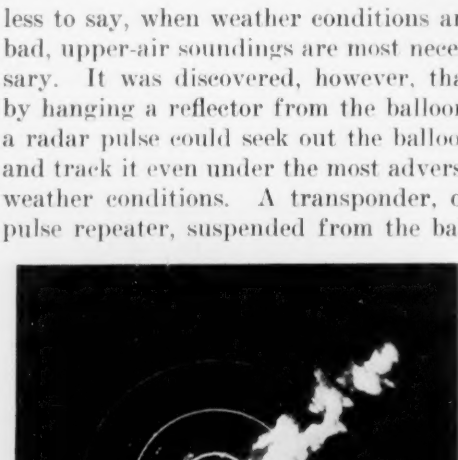


U. S. Navy Photo

A COLD FRONT

REPRESENTED BY THE ROW OF BRIGHT DOTS ALIGNED IN A NE-SW DIRECTION AS IT APPROACHES NAVAL AIR STATION, LAKEHURST, N. J., IN THE CENTER. THESE DOTS ARE THUNDERSTORM AREAS. THE RADAR RANGE COVERS 50 MILES. THE CONCENTRIC CIRCLES INDICATE 10-MILE INTERVALS.

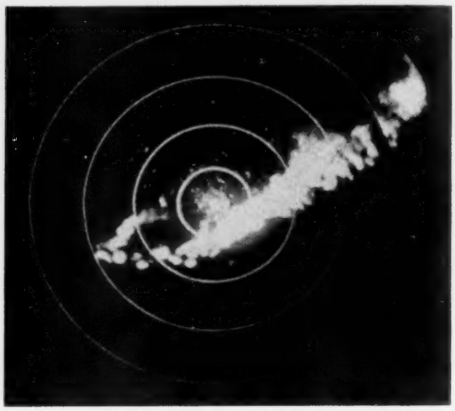
less to say, when weather conditions are bad, upper-air soundings are most necessary. It was discovered, however, that by hanging a reflector from the balloon, a radar pulse could seek out the balloon and track it even under the most adverse weather conditions. A transponder, or pulse repeater, suspended from the balloon could pick up the original radar pulse and amplify it before returning it, thus permitting tracking to far greater altitudes, under stronger wind conditions, and to far greater distances than ever before. Not only did upper-air wind soundings become possible under any and all weather conditions, but also radar added one more parameter to those normally determinable. Range is given as well as elevation and azimuth. The crippling assumption of a constant rate of ascent of the balloon was eliminated.



U. S. Navy Photo

THE SAME COLD FRONT

AS IT PASSES LAKEHURST.



U. S. Navy Photo

THE SAME COLD FRONT

ONE AND ONE-HALF HOURS LATER.

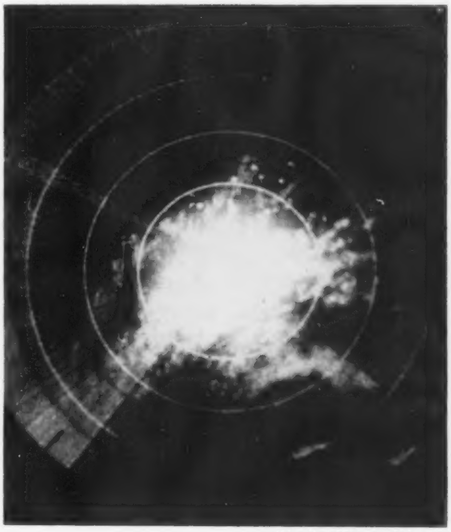
Radar Storm Detection. The second great radar contribution stemmed from the discovery that frequently a pip was observed on a radar scope which could not be accounted for by approaching aircraft. The echo appearing on the plan-position-indicator (the PPI scope) had too irregular outlines, too great an area and height, to result from reflection from ships or planes. It was determined that precipitating clouds produced these echoes. The implications of this discovery were immediate and obvious. The approach of frontal systems could be observed 150 miles away. A single thunderstorm cloud could be tracked across the country. The approach of "weather" could be timed exactly. Air-

craft could be directed to thin spots in a front or around a cumulonimbus cloud and thus be able to fly through weather formerly considered impassable. The limitation of range of radar due to the boundary of the optical horizon was counteracted when necessary by placing the radar in aircraft. The radar pulse originating within the plane was not stopped short by the optical horizon. If needed, the information contained in the weather-produced echoes on the plane's PPI scope could be relayed to the ground. The Weather Reconnaissance Squadron planes were all equipped with aircraft radar suitable for storm detection. In their search for typhoons and hurricanes, the planes were greatly aided by the characteristic radar pattern of the clouds surrounding these storms. It no longer was necessary to fly into the center. The calm, precipitation-free eye of the storm appeared as an echo-free circle within the spiral configuration of the tropical storm's clouds.

Prognosis

Some of the war-evolved techniques have been discussed. To carry the analogy of meteorology's development somewhat further, the question can be raised: "Has meteorology achieved full maturity?" The answer must be No. Meteorology has done a man's work but has not yet achieved manhood. Look at its record during the war years. Almost all the progress has followed the direction of data collection. Whether it resulted from climatological records, the statistical correlations of long-range forecasting, aircraft reconnaissance, or the new radar techniques, the end product has been data and yet more data.

The progress of any science has always before followed the same general lines. The collection of facts has been only the first step in its development. The second resulted from deductive reasoning whereby the facts were sorted, classified, and summarized into equations. Finally, by inductive processes, new equations for natural phenomena are developed. Only at this stage of development can a science be considered fully matured.



U. S. Navy Photo

A HURRICANE

AS IT FIRST APPEARED ON THE RADAR SCOPE AT LAKEHURST, N. J., SEPTEMBER 14, 1944.

At present, meteorology has more facts than it can use to the fullest extent. With the urgent need to investigate the upper atmosphere in connection with atomic research, guided missiles, and the rockets program, this situation is becoming further exaggerated. It must be understood that data are valuable—the more data, the greater the value. But the collection of data is not to be confused with an end in itself.

The correlation of data is the desired end. Eventually, weather forecasting must be resolved into a series of formulae which will permit the neophyte in the science to insert proper values of the variables into a series of equations. He can then solve for x and get the forecast weather. Only when mathematics, substituted for experience, can provide a forecast will meteorology have progressed significantly as a science.

Since these are days of electronic in-

ventions, the goal for which meteorologists must work is already in sight. Whereas formerly the solution of a problem with as many variables as atmospheric physics would have been deemed impossible, at present there are available electronic calculators to give the solutions. These machines are capable of solving some 100,000 differential equations a minute. Had we the proper equations to impress on the machine, we would need only to feed in the synoptic data and take out the weather forecast for one, two, or five days.

More than that—weather at any given locality is undoubtedly a complex function of variables at other geographic locations. Whether Washington, D. C., experiences rain next Tuesday may depend upon the temperature in Greenland now, the pressure in the Antarctic last year, the rainfall in the Mojave Desert last month. It is not inconceivable that with the energy of atomic fission harnessed and available, it will be possible to alter any one of these conditions and change the weather experienced at the capital at will. This would be feasible only if it could be ascertained where the energy could be most economically applied and what the effect of such changes would be on all other parts of the world. The rapidity of calculation of the electronic calculator would permit fulfillment of these two requirements.

But first the fundamental equations which determine the circulation of the atmosphere must be developed. Present-day meteorologists recognize the need. The Navy, for example, is sponsoring fundamental research on cyclogenesis, vertical motion in the atmosphere, heat exchange, and many other weather-related problems. With unimpeded progress in the collection of data and fundamental research in the physics of the atmosphere, meteorology should soon come of age.

THE HAKLUYT SOCIETY: ITS FIRST HUNDRED YEARS

By CHARLES F. MULLETT
DEPARTMENT OF HISTORY, UNIVERSITY OF MISSOURI

QUITE unobtrusively in 1846 a most significant learned Society came into existence and this year celebrates its first centennial. While no attempt will here be made to survey its whole career or to describe its full importance, it is submitted that the occasion does warrant attention. In the midst of national chaos and international anarchy the birthyear of a Society "for the purpose of printing rare or unpublished Voyages and Travels," a Society which sought by this means to open "an easier access to the sources of a branch of knowledge, which yields to none in importance, and is superior to most in agreeable variety," is likely to pass unnoticed save in the narrowest circles. Yet through the years—and none can deny that 1846–1946 has seldom been surpassed as a century of change, crisis, and indecision not only in material but in spiritual and intellectual matters as well—the Society has continued to meet for the discussion of what at times seemed esoteric, almost whimsical, problems and to publish or sponsor well over 200 volumes of what must often appear to the hasty as no more than antiquarian folklore.

With its inspirer, Richard Hakluyt, Preacher (1552?–1616), the Society has been both historian and geographer. Its narratives of travelers have acquainted students "with the earth, its inhabitants and productions." They have exhibited

> the growth of intercourse among mankind, with its effects upon civilization, and, while instructing, they at the same time awaken attention by recounting the toils and adventures of those who first explored unknown and distant regions.

So unobtrusive was the Society in its founding and career, however, that one will look in vain for any formal account of its purpose and philosophy beyond the few scattered phrases here quoted.

Without fanfare it published its first volume in 1847 and has kept doggedly at this function ever since. Wars may come and depressions may go, but the Society has pursued its way with scarcely a reference to passing events. In his preface to *The Voyage of Sir Henry Middleton to the Moluccas 1604–1606* (1943), the Society's president and a most distinguished historical geographer, Sir William Foster, did permit himself to observe that "the countries with which it is chiefly concerned (and several others) have been overwhelmed by a yellow flood of Japanese invasion. No one doubts, however, that this phase is merely temporary. . . ." Therefore, why should one, Sir William seems to inquire, disrupt and distort the true proportions of the past by interpolations on circumstances so temporal as a Japanese occupation? Art (that is, Clio) is long, invasions are but fleeting phenomena. Likewise, no apologies about the interruptions and shortages caused by the war in Europe and Asia mark this or any other volume. The eternal verities are much more significant. In 1916 the Society commemorated the 300th anniversary of Richard Hakluyt's death. The president, Albert Gray, in his address had no hesitation in giving the "lamented death" of Sir Clements Markham, who for 60 years had endowed the Society with his unwearied labors in editing and translating, as much consideration as "the dark cloud of war": they shared a sentence. From this he passed quickly on to mention the forth-

coming publications and to discuss informally "the place of Hakluyt and his great work in the political and literary history of England."

The remarks in the following pages have value in that they apply alike to Hakluyt and to the Society which bears his name. *The Principal Voyages, Traffiques and Discoveries of the English Nation made by Sea or over Land to the most remote and farthest distant quarters of the earth, at any time within the compass of these 1600 years* (12 vols., Glasgow, 1903–5) "may be regarded from the point of view of history, from that of literature or from that of empire building, and it is notable in all these aspects." Furthermore, Hakluyt's epic work may also be regarded as a notable example of the Elizabethan outlook, an outlook which interestingly enough found substantial and vivid exposition in the writings of Clements Markham's own Elizabethan ancestor, Gervase Markham (1568–1637). This outlook was one of curiosity, an industrious curiosity which led to the exploration not merely of unknown or little-known lands but also of equally unknown or little-known fields of knowledge, a curiosity which sought on every side to orient theory in experience, to test by specific observation or experiment the common generalizations.

Yet with Gray one may ask: Could "the editor of a compilation of traveller's tales, mostly transcribed, perhaps partly written to dictation, be classed as a historian . . . or . . . be placed in the world of letters in the rank of authors?" Hakluyt's own work was "little beyond the prefaces and dedicatory epistles"; and he never claimed to be more than a humble editor who rescued from oblivion records that "lay so dispersed, scattered and hidden in several hucksters' hands that I now wonder at my selfe to see how I was able to endure the delayes curiosity and backwardnesse of many from whom I was to receive my originals." Fortunately the patriotism, curiosity, and no doubt sheer enthusiasm of one who was both Herodotus and empire-builder kept Hakluyt going. The result is the prose epic of the English nation, heroic deeds nobly told.

The Society has adhered not ostentatiously but quietly and naturally to Hakluyt's own qualities. From the first volume, *The Observations of Sir Richard Hawkins Knight, in his Voiage into the South Sea Anno Domini, 1593* (1847), down to the aforementioned *Voyage of Sir Henry Middleton* (1943), the editor has kept very much in the background. The original narrative is the thing. The editor of the *Observations*

> confined his labours to reproducing the text of the original, with only such slight observations as were necessary where the sense of the author had been obviously marred by a misprint [he was reproducing the printed text of 1622]; giving such explanations of obsolete words and technical terms as might embarrass an unprofessional reader; identifying the places visited with their modern appellation, where practicable; and adding such remarks as occurred to him while correcting the proof sheets.

The introduction included sound but brief reference to the hazards of voyaging in Elizabeth's day, the equipment of the ships, the administration of expeditions, the career of Hawkins, and the consensus of opinion that the *Observations* "must take their station in the very first rank of our old sea voyages."

The editorial work and the introductions a century later are somewhat fuller, but this follows less from the intrusion of the editor than from present-day historiographical tendencies. In 1943 Foster produced a text "with the addition of such other contemporary material as could be found, bearing upon the voyage." His lengthy introduction and notes supplied the Elizabethan background, political and economic, related the voyage of Middleton to contemporary naval and commercial developments, de-

scribed the organization of the expedition, discussed other English activity in the Far East, commented on Dutch rivalry, informed readers about Middleton, listed some bibliography, and elucidated and identified some terms and places. Nonetheless, the narrative, no matter how heightened its meaning through such loving care, is still the thing.

WHEN the Society was founded in 1846 it set forth in the first article of its few laws the guiding purpose:

> The object of this Society shall be to print, for distribution among its members, rare and valuable Voyages, Travels, Naval Expeditions, and other geographical records, from an early period to the beginning of the eighteenth century.

The only deviation from this modest yet comprehensive policy has been the elimination of the terminal date, for occasionally volumes have dealt with the eighteenth and early nineteenth centuries. The other articles covered such mundane matters as subscriptions, organization, administration of the Society's affairs, and rules concerning publications, the individual editors of which receive nothing more than 25 copies of the published work.

Throughout the years the Society briefly reported its ups and downs in membership, its publications, past and prospective, its financial status, which seems generally to have been good, its officers, and on occasion the passing of some distinguished members. At the beginning it numbered somewhat fewer than 250 members, but among them were men of substance in every field of endeavor—admirals, bishops, politicians, businessmen, and scholars. John Barrow, the assiduous promoter of Arctic exploration, Charles Dickens, Sir John Herschel, and William Whewell were charter members. The subscription fee of one guinea which entitled members to receive the publications was certainly not prohibitive for those interested; it has not been increased. In 1849 the Council could report a membership of 276 and a generally cordial reception, private and public, for its publications. At the end of the first decade the subscribers totaled about 320, but thereafter the number declined and remained discouragingly low for several years. In 1873 it was 214; in 1878, 248; and in 1889, 278, the Society seeming to suffer from the preponderance of older men among its members. After 1900 a definite upturn was obvious, and the Society was then in a position to carry through more of its publication projects, which were intended to be at least two a year. In 1930 the membership exceeded 630, many of which were libraries and societies.

Large or small, however, the Society could with complete accuracy declare in 1901 that it had "not confined its selection to the books of English travellers, to a particular age, or to particular regions." In time it ranged from the thirteenth to the nineteenth centuries, with greatest emphasis on the 150 years after Columbus, and in space it covered the world. As this catholicity became increasingly apparent and was consistently adhered to, subscriptions began to come in from an ever-widening area until the membership was as completely international as the substance of its publications. Nevertheless, its high standard of historical purpose did not deter the Council from taking pride in 1865 in the practical value of a volume on the early exploration of Hudson Bay, which had provided Captain Penny, then in search of Sir John Franklin, with his most complete navigation guide for part of the Hudson Bay region: so the travels "may often be of real practical use to seamen and explorers."

In the largest sense the value of the magnificent series is of course primarily historical. We may agree with the foremost authority on the subject, J. A.

Williamson, that the "history of Elizabethan expansion is to a great extent the work of Richard Hakluyt, to a greater extent perhaps than the record of any other large movement can be ascribed to the labors of any one historian." But the truth of this can be fully realized only if attention be paid to the work which Hakluyt inspired. In contrast to Samuel Purchas, B.D. (1577–1626), who in *Hakluytus Posthumus or Purchas His Pilgrimes. Contayning a History of the World in Sea Voyages and Lande Travells by Englishmen and others* (20 vols., Glasgow, 1905–7) attempted to carry on his work, Hakluyt was an almost perfect editor. He "gathered the materials of a history and dealt so cunningly with them that they became a history while retaining their guise of raw materials"; but Purchas "arranged a museum." Notwithstanding his great merits—and only reading will reveal them—Hakluyt was not complete, and it is the peculiar virtue of the Society which bears his name that it has performed a miracle; it has successfully and appropriately gilded the lily. Without the Society, as indeed without the empire resulting from the expansion he at once narrated and encouraged, Hakluyt would have received far less consideration.

The Hakluyt Society publications, like those of Hakluyt himself, are not to be viewed exclusively from the standpoint of expansion. While it would be tedious to list the publications, one must emphasize the range. The narratives of French, Dutch, Spanish, Portuguese, German, Italian, and Danish, as well as English, travelers are reproduced. These men, representing a wide variety of professions and vocations, visited Europe, Asia, Africa, the Americas, and the islands of the sea. Neither tropic heat nor arctic cold stayed their steps. From their accounts one may learn much of the history and society of the countries visited, much of the expansion process, and, perhaps most important of all, the outlook of the travelers and by extension their lives and times. Indeed the voyages and descriptions here published convey deep insight into contemporary European social and intellectual conditions. They are particularly valuable for reconstructing the scientific, the moral and religious, and the broadly social views held by the travelers themselves and the environment from which they sprang. No one wishing to grasp to the fullest the history of the period in which these narratives were first composed should neglect them.

These visitors to other worlds, whether merchants, priests, diplomatists, or mere wanderers, genteel or otherwise, on the face of the earth, constantly faced natural phenomena, political and social institutions, and currents of opinion the like of which they had never encountered before. Inevitably they compared and contrasted and not infrequently, as they penetrated to the essential core of their discoveries, they remarked similarities to those things they had known at home. Furthermore, though they knew it not, they were in their own way following the precept of that great twelfth-century explorer in various realms of science, Adelard of Bath: "It is worth while to visit learned men of different nations, and to remember whatever you find is most excellent in each case." If learning as Adelard knew it was seldom present, knowledge abounded.

The epic accounts preserved in Hakluyt, Purchas, and the volumes of this Society—not to specify the many other handsome collections—provide a majestic autobiography of an age, fascinating and comprehensive. How and why these men of whatsoever origin and interest set down their reactions to the worlds of their explorations is part of the essential history of the countries they represented; what they described belongs to the history of worlds overseas. The whole is a magnificent panorama of world

history. From the outset, the urge of travelers to keep diaries or to write up their experiences on returning home has been natural and prolific. Many of these immediately became available in the pages of Hakluyt, his successor Purchas, in other collections, or in isolated publications. The special distinction of the Hakluyt Society has been the completeness and the authority with which such diaries and accounts have been gathered up, given dependable editorial sponsorship, and made generally available in an intelligible dress. It is scarcely too much to say that the unknown has become known, the rare has become common, and the incomplete and mutilated has become complete and restored.

The products of course have an interest all their own. The motley crew of adventurers had personality. Some were extraordinarily skilful narrators, others extraordinarily unskilful, at least so far as superficial trappings were concerned. Whatever their quality in this regard, however, their experiences and characters alike transcended syntax, and, so far as English travelers were concerned, their narratives are often "admirable examples of English prose at the stage of its most robust development." The bizarre and the commonplace, the journey and the destination, the land and the people, the ideas and the institutions, leap from their pages. Not all they wrote can be taken as truth, but they assembled the ingredients of truth. Samuel Purchas was no doubt a bad editor in many ways, but he fully saw the importance of geography for history. Moreover, his declaration that "the necessitie of a Historie is, as of a sworne Witnesse, to say the truth, all the truth (in just discretion) and nothing but the truth" derived in no small measure from his appreciation of the value of those divers journals he pored over so assiduously. The Hakluyt Society volumes add bountiful substance to his contention, but like those very volumes, no small part of the Society's value is the outlook its activity and devotion reflect. A learned Society with one hundred years of history stands as a beacon light in a stormy world. May our grandchildren celebrate its second centennial!

PHYSALIA

The hydrozoan spew of earth's pelagic womb
Produced Physalia, queen coelenterate,
An iridescent flagship, fringed, globate,
To lead each year's armada to its doom.

From freedom of the sea's wide lane
Wind driven, the pint-sized Man of War
With sheer topsail and frail pneumatophore
Becomes a bauble which the sand crabs claim.

A tropic quiet marks the listless day
While bathe in tidal pool, the fair
Of face and limb, unconscious where
The ten-foot strands of poison stray.

An accidental touch everts each sac
Of barbed nematocyst. In seried rows
Like branding rods the acid protein grows
A livid trail to mark the dread attack.

No mean opponent this whose thousand darts
Of liquid fire retain their venom, dry
For months, whose jellied forms belie
The shock and torment which their sting imparts.

With neural net of prime simplicity
Predating brain, and vascular canal
Predating heart this gastral sac
May shed some light on our duplicity.
So close beneath the skin the bestial!
To look like gods and yet so much to lack!

JOHN G. SINCLAIR, 1946

THE HERBARIUM

By F. R. FOSBERG

SCIENTISTS have two great sources of information. One is, of course, scientific literature. This is the record of observations and conclusions of workers since science began. Because it is recorded information it must be regarded as a secondary source. It is subject to a considerable increment of error because it has been written down by the human hand. The same increment is also inherent in the raw data recorded from experiment or field observation.

The only primary source is in the actual objects of study. In astronomy this source is in the heavens and is accessible by means of telescopes and cameras. In geology and geography it is the earth. In physics it is the universe, from the infinitely large to the infinitely small. In chemistry it is the multitude of combinations of the elements that make up the tangible universe. In ecology and its branches it is the biotic community that covers the surface of the earth. In anthropology and its subdivisions (psychology, sociology, ethnology, archeology, etc.) it is man and his works. In biology it is organisms.

One of the principal problems in each of the sciences is that of gathering together in accessible form the objects of study. The problem is sometimes partially solved in most of them by photography. The limitations of this method make it, at best, a partial solution. In most branches of science recourse must be had to collections of recorded data, thus introducing the increment of error. In a fortunate few the museum affords a practical means of concentrating in one place and in convenient form for study primary materials from over the entire earth. It is natural history (which may perhaps be defined as the unexperimental part of biology) that has, by the very nature of its objects of study, been enabled to make the fullest use of the museum as a tool. Of course, there are many other sorts of scientific museums, mostly pertaining to certain branches of anthropology and geology. In some of these (that, is archeology, history, mineralogy, petrology, paleontology, and physical anthropology—the last two equally branches of biology or natural history) the museum is the basis of most research. However, even in one or two of these, difficulties are inherent. Architecture, airplanes, and other large machines are expensive and difficult to house, while physical anthropological material is often subject to certain emotional associations that make its acquisition difficult.

It is in biological taxonomy that the museum reaches its fullest development and its greatest usefulness. It is here at the very roots of the entire science and of its utility to other branches of science and human activity. The concentration of material from many places and its subsequent preservation frees the science, in a large measure, from the tyranny of words and the errors that occur in their recording, use, and interpretation. A taxonomic work that is based upon a properly collected and preserved series of specimens need not depend for its entire value upon the words in which it is expressed or the conclusions drawn by its author. The specimens which are its foundation will last indefinitely and may always be examined, if they are so cited as to be identifiable.

The special type of museum to be considered here is, for historical reasons, called a herbarium. Early systematic

botany was preoccupied with medicinal plants, generally termed herbs. It also grew up in a part of the world where much of the flora was composed of grasses and other herbs, as opposed to shrubs and trees. One or both of these facts may have influenced Linnaeus in the coining of the simple and usable word *herbarium* for what had previously been variously called a *hcrtus siccus, hortus mortuus, hortus hiemalis,* or *phytophylacium.* At any rate, it may be due to these predisposing causes as well as to the position of authority of Linnaeus that the word was generally taken up by the botanical world and is in universal use today.

With proper preparation and adequate care dried plant specimens will last indefinitely. The herbaria of Ghini (1519–1556) and Caesalpinus (1519–1603) were, at the beginning of the second World War, still in existence in Italy. Pressed specimens attached to uniform-sized sheets of paper also lend themselves to filing. The part of the paper not covered by the plant is inevitably, and properly, used for jotting down observations for future reference of the person making them or to direct attention of future workers to peculiarities of the specimen.

In brief, the modern herbarium is a great filing system for information about plants, both primary in the form of actual specimens of the plants and secondary in the form of published information, pictures, and recorded notes. An important part of the herbarium is the staff of botanists and other workers who use it and make it function.

Literally speaking, any collection of dried plants prepared for study is a herbarium, no matter how it is arranged, filed, or preserved. However, several hundred years of experience have resulted in more or less standard methods being evolved, to such an extent that a botanist from one herbarium is quite at home in any other, and specimens are exchanged between them perfectly satisfactorily, as well as lent back and forth.

Pressed plant specimens are mounted on standard-sized sheets of heavy white paper, with the label in the lower left-hand corner, placed in manila folders, one species in a folder, these in heavier folders, one genus to a folder. These are filed in upright filing cases of a more or less uniform design, with pigeonholes to fit a convenient number of specimens. There are several systems of arrangement, all familiar to any botanist, so that there is seldom any difficulty in finding the specimens of any desired species.

This system is ideal also for the inclusion of notes, photographs, drawings, plates, and clippings from published literature, which are mounted on similar sheets of paper and filed under their proper family, genus, or species.

Under the ministrations of a competent staff, there is a continual influx of plants, photos, and information of all sorts. The main source is, of course, field work done by the members of the staff. Specimens are collected not only for inclusion in the herbarium, but so that duplicates may be exchanged with other institutions, bringing a flow of specimens from them, along with the benefit of the experience of other botanists as contained in the identifications and notes on these specimens. Thus the effectiveness of each botanist is multiplied and his knowledge and experience made widely available. Specimens also come in for identification. The services of the botanists of most herbaria are always at the command of anyone who will take the trouble to send in a good specimen of any plant that he wants identified. The plant, if it is properly pressed and accompanied by data as to place and circumstances of origin, is usually placed in the herbarium. Most

botanists are specialists either in one or more groups of plants or in the flora of a particular region. Because of this, specimens are sent to him from institutions and individuals all over the world to be identified and added to the herbarium in which he works. Thus, in return for a service which could be found nowhere else, he is given access to much more material of his specialty than he could ever hope to collect by himself. And the accumulation of information in his institution grows.

One of the most important functions performed by a herbarium is that of preserving and caring for valuable historically important specimens. These are largely what are called types. Types are specimens upon which species have been based and which are thus the points of reference for the names given to these species. However inadequately the species may have been described or whatever the changes undergone by the meanings of words, if these original specimens are preserved and available, all doubts as to the application of their names are avoided. Such specimens are, of course, irreplacable, and their care is perhaps the most important single responsibility of any herbarium to which types are entrusted. They should be regarded as a part of the general heritage of the science of botany, rather than as the private possessions of any one institution, regardless of their legal status. Special techniques are employed in their preservation and special procedures worked out for their use and availability. An increasingly important modern practice is the exchange between herbaria of photographs of types and other important specimens.

The activities of the staff members roughly classify themselves into two interlocking categories. First is the securing and incorporation of material into the herbarium. This includes everything from collecting specimens in the field to filing them away in the folders after they have been identified and mounted. The other sort of activity is the utilization of this great reservoir of information. Study and comparison of the specimens and correlation of the information obtained with what is already known results in a continuous stream of identifications, answers to questions from all imaginable sources, and publications making the results of this research generally available.

The continual flow of new specimens, questions, and requests for information is second only to the staff members' own field work in stimulating this search for new information and clarification of old. In the course of attempting to identify specimens and answer inquiries, gaps in our knowledge are encountered, defects in the classification, misinterpretations of fact, undescribed species of plants, unsatisfactory keys for identification. All of these are challenges to the active mind of the botanist. They may lead him far afield in his attempts to remedy the deficiency, but he is seldom satisfied until the task is done. And all the time new bits of information are being incorporated into the great body of fact that is the herbarium. The result is that a study of almost any group of plants in a large herbarium will yield a quantity of previously unsuspected information, made obvious and significant by being brought together in the continual process of organizing and adding to the collection.

Until recently the herbarium has been regarded as the exclusive bailiwick of the purely systematic botanist. Those who dealt with living plants regarded the physiological laboratory as the only reputable place for such study. The outdoors was usually left to the systematist, who too often regarded it only as a source of herbarium specimens.

However, when the systematist began to realize that the units he was studying were really populations and that the fundamental principle behind his classifications was really evolution, and when the physiologist started to venture out into the field and to call himself an ecologist, the two sometimes met and talked. The more alert ones among them discovered that they needed each other to help answer some of the questions that their new contacts and concepts raised. Geneticists also arrived on the scene. They commenced to infiltrate the hitherto exclusive domains of the cytologists and the systematists as well as, once in a while, to venture also out into the field to examine their plants as natural populations. The different sciences came to lose their exclusiveness. The systematist began to lose his austerity, the followers of the newer branches to get over their inferiority complexes, and such hybrid individuals as experimental taxonomists, cytogeneticists, cytotaxonomists, and even cytogeographers made an appearance. The practical plant breeders smelled something that might be put to their purposes. When they showed an interest, a few of the keener botanists jumped at the chance to put them to work helping solve some of the fundamental problems that required several kinds of expensive effort.

One man, who is a happy combination of horticulturist and highly competent systematic botanist, has long been doing valuable practical work on cultivated plants in the herbarium. This is Liberty Hyde Bailey. Many others whose resources were much greater missed opportunities that may never come again to effect this union of two sciences for mutual profit, because of lack of the education or mental acuteness to see the possibilities.

It remained for another man, one who calls himself a geneticist but who is really one of the outstanding biological thinkers and scientific philosophers of our time, to demonstrate and to emphasize the fact that the herbarium should be a valuable tool and laboratory for many different branches of botanical investigation besides pure systematics. Edgar Anderson, in his writings on new techniques for population study and the analysis of variation, has pointed the way toward the herbarium of the future.

The task of the herbarium, which is still to be an organized collection of dried plant specimens, has suddenly grown from that of preserving series of specimens to show only the range of variation of species and their geographical distribution and vouchers for the fixing of names to a much broader scope. Mass collections to show population structure, range and distribution of variation, this in time as well as space; specimens of cultivated plants to document and provide comparative material for the work of the applied economic botanist or plant breeder; specimens which are vouchers for the work of the geneticist and the experimental taxonomist; material for intensive phylogenetic research; specimens of the abnormalities produced by the experimental physiologist; specimens which form the basis of ecological studies; and plants whose chromosomes have been counted or which have been the subject of important morphological and physiological investigations all now come within the domain of the herbarium's interests. There is a crying need for this sort of material to be preserved in an always available form and place. The herbarium worker has had four hundred years of experience in the technique that will satisfy this need. In the face of his reluctance toward change, this task is being forced upon him. It will be more and more forced upon him in the future. Willy-nilly he will be removed from his position of aloofness and

from the position of unappreciated and unrespected servant where he is placed by some of his colleagues. He will be forced to become a full and active partner in the enterprise of biology. The effects, both upon him and upon biology can be expected to be very healthful.

One of the most important tasks for the herbarium, more urgent than ever now that man's numbers have so increased and his destructive capacities have become so great, is the preservation of data on the original vegetation of the earth. It is being destroyed with tragic rapidity and with no regard for what interest it might have in the future. The only documented records that will remain of much of it will be on the labels and notes accompanying herbarium specimens. The rescuing of these data, the raw material of vegetation study and plant geography as well as of systematic botany, is perhaps the most pressing function of the herbarium and its staff. All collecting done is a contribution to this fund of information. Every herbarium worker should, if possible, spend a substantial part of his time collecting. Institutions maintaining herbaria should do everything in their power to make this possible.

Another very real, though perhaps unintended, function of a herbarium is to provide a meeting place for botanists. They are attracted by the collection of plants and by the accomplishments of the staff members and are thus brought into contact with one another. This provides an important opportunity for exchange of ideas and for mutual benefit from experience. The whole science gains from the stimulation to thought and from the mutual understanding and cooperation resulting from these contacts that casually take place in the herbarium.

Space and an adequate and continued income have always been the problems that have plagued the herbarium administrator. Herbarium buildings are, almost without exception, either buildings that have been built for other purposes and adapted or parts of university buildings that have been built to serve all of botany or biology. Few buildings have ever been designed as herbaria and all too few have been built with much thought for future expansion. Consequently the normal activities and interests of many herbaria have been cramped and stifled by lack of space. The basic income of most herbaria is provided by the institutions that maintain them. This is almost never adequate for full functioning of the herbaria. The difference, in those few cases where it has been made up, has been provided by gifts, either from patrons who have had an interest in the work of the institutions and their staffs or, in all too few cases as yet, from corporations and agencies who have profited directly or indirectly from the work carried on. Such gifts have been largely responsible for some of the greatest steps in the outstanding progress in taxonomic research and botanical exploration accomplished in the United States in the past half-century. It is to be hoped that with the broadening interests and utility of herbaria such gifts will continue and multiply many times.

Much of the success of a herbarium is dependent upon the personality and ability of its administrative head. The ideal herbarium administrator would be an outstanding systematic botanist with broad interests extending into many groups of plants, regions of the earth, and types of problems. This would give him a broad base for understanding the multitudinous activities of the herbarium and its different staff members. He would have a long-range viewpoint, realizing that any work, material, or money put into a herbarium is a long-term investment, expected to serve for ages.

He would seek out the opinions of all who had experience with a given topic or field. He would select staff members for demonstrated ability and interest in their work and would let this be their compulsion to work. He would have a genuine love for people as individuals and interest in them as well as an even disposition and the ability to remain unruffled by the inevitably strong individualities of his staff members. He would be able to regard the research problems and interests of his staff as of even more importance than his own and to place the interests of his institution as a part of the greater entity of biology above all else. Perhaps most important of all, he would be able to maintain friendly relations and cooperation with the rest of botany and with the public. And he would be able and willing to fight, when necessary, with his superiors, be they college presidents, regents, trustees, or governmental administrators, to see that his institution and staff were not hampered or restricted in following where their enthusiasm led them in their work. It would be a fortunate institution, indeed, that had such a director.

The characteristics of a herbarium may be summarized by regarding it as a great organism into which is maintained a flow of specimens and unorganized data. The staff of botanists, technicians, clerks, and other workers furnish the driving force and controlling influence. With an adequate staff and support the organism maintains an active growth. There is a continuous production of results in the form of services to other human enterprises and of additions to the general fund of organized knowledge that is science. Without these two requisites disintegration rapidly sets in, and the investment in effort, time, intellect, and money is wasted.

GOVERNMENT AND THE MEASUREMENT OF OPINION*

By SAMUEL A. STOUFFER
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LONG before the war social scientists were studying and documenting the proposition that society's greatest problem is to develop mechanisms of government adaptable to the complex social order produced by modern science and technology. And whether we like it or not, as has so often been said, big government is here to stay.

There is no less reason for us to fear big government today than in the time of Thomas Jefferson. But fear cannot reverse the technological trends which have substituted the airplane for the stagecoach. Our problem is not how we can prevent big government, but rather how, having it, we can keep it both responsive and responsible to the people. If the liberties which were slowly and painfully won through the long centuries of the history of Western civilization are to be preserved, government must be not only for the people but also of and by the people.

Big government can be responsive and responsible to the people only if there are efficient channels of communication between the governed and the governors. Let us discuss some developments of the past decade for the improvement of these channels of communication; developments which can prove of considerable importance to the preservation of our civilization. They are even yet in their infancy, but we have seen enough to get a foreshadowing of what they promise for the future.

How does Washington find out what the people are thinking? There are several channels.

One is the press and radio. We can admit that the press often represents the publishers' personal viewpoint and not the public's and still be thankful for the freedom it possesses. Abuses by government are not likely to go unchallenged or achievements of government undefended somewhere in print or on the air. Nevertheless, the press taken as a whole is hardly the voice of the people, as recent presidential campaigns have abundantly demonstrated.

Another channel of communication between the people and Washington consists of letters to members of Congress or executive officials. This freedom to write or petition is a precious one and is influential, but few would hazard the claim that such mail mirrors public opinion. When the future of American preparedness trembled in the balance in the summer of 1941, the House of Representatives voting by a majority of only one to extend Selective Service, a study of the Congressional mail showed that the mail was running 90 percent against extension of Selective Service in spite of the fact that public opinion polls showed the majority of the public in favor.

A third means of communication is face-to-face contact, often by the representatives of pressure groups. Statements like "I represent the view of 8,000,000 American women" or "This is what the farmers want" or the church people want, or whatever the group may be, are sometimes potent determiners of

* From an address before the St. Louis Meeting, A.A.A.S., March 28, 1946.

Congressional or executive action. It is the fashion among liberals to condemn lobbyists (except, of course, lobbyists for good liberal causes), even though it should be obvious that *organization* of opinion is necessary to get desired political action or prevent undesired political action. A just criticism, however, can properly be made of tricks of lobbyists in bluffing about what the public wants or will not stand for and in manufacturing synthetic public pressure through word of mouth, letters, and telegrams.

A fourth method of communication is, of course, elections, when the people have an opportunity to express their opinions by voting the rascals out or returning those whom they consider faithful servants. So many factors enter into a vote for a particular individual that it is seldom possible to interpret his election as a mandate from the people on a particular issue. In some states the expensive referendum procedure has been extensively used, sometimes with good results on issues which have been widely debated but with less satisfactory results on issues which are complicated and do not admit of a simple yes-or-no answer.

All these channels of communication, the press and radio, letters, face-to-face contacts, and elections, are obviously vital to operating a government responsive to the people, but seldom do they succeed in gauging according to any scientific standards of accuracy the degree to which the public is informed about an issue, the degree to which it is concerned, and the division of opinion on the issue.

The pioneer work of men like Dr. George Gallup and Elmo Roper have brought into public consciousness a fifth channel of communication which is already beginning to take its place alongside the others as a means of bringing the people and their government closer together. The idea of a public-opinion poll is an old one—straw votes have been taken for decades—but it is only in recent years that the procedures have been systematized. In so doing, the practitioners of polling have gone to the mathematical statisticians for help in devising the most efficient sampling designs. Much progress has been made in increasing accuracy at the same time that costs are reduced. Further progress may be expected. The National Research Council and the Social Science Research Council have joined hands in setting up a committee of mathematical statisticians, psychologists, sociologists, practitioners of opinion research, and important consumers. The first project of this committee, with the aid of a grant from the Rockefeller Foundation, is to review various types of sampling designs now in use and to explore the relative advantages and disadvantages of alternatives, theoretically and practically.

While the accuracy of opinion surveys depends on the selection of a representative sample of respondents, it does not depend alone on that. In fact, the sampling of respondents may be one of the relatively easier of the problems to solve. Even more important is the problem of defining the issue and selecting from the universe of possible questions which might be asked of respondents a sample of questions which will represent the attitude of respondents on that issue. Again, the mathematical statisticians have been making progress in formulating what is meant by sampling from a universe of items on a particular issue and in devising means of testing the consistency and representativeness of the items selected. Compared with the developments in the sampling of respondents, the developments in the sampling of items are still in a relatively primitive state. Much progress is to be expected in the next few years, and the joint committee of the National Research Council

and Social Science Research Council is naturally concerned with such problems.

It is to be expected that opinion surveys would be viewed with some suspicion by members of Congress and by other officials within the government. When Senator X stands on the floor of the Senate and says, "I speak with the voice of all the people of my great and sovereign state," he can be subject to considerable embarrassment if a scientifically designed poll shows that only 10 percent of his people think on the issue the way he does. In a sense, the very idea of a poll is an invasion of the sacred prerogative of members of Congress to be the spokesmen of their constituents. But Senator X may also have more legitimate grounds for suspicion. In the wrong hands, this new device for recording public opinion can be abused. It is possible for clever publicists to select certain items favorable to their side of a case, suppress others, and make a presentation in the name of science which is completely misleading. This has been known to happen in the commercial field, and the best practitioners are always on their guard against it. It could happen, and probably has happened, in government. The danger may be expected to increase as more and more leaders discover what a powerful instrument for influencing action a supposedly scientific analysis of the public will can be.

There are two further dangers of public-opinion polls which should be mentioned. One is the danger of jumping honestly but too hastily to the conclusion, from a reported survey, that the public mind is determined in a given direction. The other is the danger that polls will have too much, rather than too little, influence on governmental action. Let us take them up in turn.

First, the danger of jumping honestly but too hastily to conclusions from a reported survey: Polls taken shortly before the defeat of Japan showed that the American public was in favor of executing or at least dethroning Hirohito and that very few favored using him as a tool to carry out our occupation designs. Yet when Hirohito was kept on the throne there was no outcry against it from the people. Evidently, the original opinion expressed by the respondents was not an opinion based on a review of the contingencies and was not held with great intensity. The next few years in the development of public-opinion surveys are likely to see much progress in study design so that one can determine, more accurately than present methods permit, how well informed the respondents are about contingencies and so that one can estimate how the opinion could be expected to shift under different contingencies.

The need would seem obvious. Three years ago the Research Branch of the Information and Education Division in the War Department asked a representative cross section of soldiers whether they would like to get more education after the war. About one-third of the men said Yes. What a bonanza for the educational institutions! But wait—only 4 percent said they would go back to school if they could get a good job after the war and if the government would not provide any educational subsidy. (This study was made before the passage of the GI bill.) A further analysis of the responses led to an estimate that 7 percent would go back to full-time school, given a moderate government subsidy. This figure was used by the President and Congress in estimating the educational cost of the GI bill. Opinion studies in the Army subsequent to the passage of the bill raised Army estimates, but current figures on full-time school attendance by veterans are still only about 2 or 3 percent higher than the one prepared three years ago—

in spite of the fact that the educational subsidy is much more generous than originally contemplated.

THE Division of Program Surveys in the United States Department of Agriculture has been outstanding in efforts to structure the situation in which a respondent is replying and get a basis for predicting what the reaction or behavior of an individual is likely to be under this or that contingency. The Division made studies during the war not only for the Department of Agriculture, but also for the Office of War Information, the Treasury Department, and other government agencies. A typical problem was that of war bond redemptions while the war was in progress. Studies showed, first, that most redemptions were for emergency purposes or capital outlay and not for buying consumer goods and, second, that the difficulty of redemption was inhibiting new purchases of bonds among small potential buyers. Careful questioning led to the conclusion that it would be safe for the Treasury to liberalize its redemption policy since it was quite likely, from an analysis of the responses, that increased bond purchases would far and away offset any increase in redemptions. This prediction was found to be correct when the Treasury, following the survey, liberalized redemption policy. During each bond drive Dr. Likert's organization made surveys of the motivations for buying, and many of the findings were directly used by the Treasury and the War Advertising Council. The important thing to note about such studies is that they require very careful advance analysis of the problem, the designing of indirect as well as direct lines of questioning, and a final analysis which depended on much more than the simple answers to a few check-list questions.

The Office of Price Administration used opinion surveys to keep close to the public pulse, as did the War Production Board. Again, caution was used about too literal interpretation of the manifest content of single items, and effort was made to analyze the problem in detail with good statistical techniques.

A rather interesting illustration of the use of scientific techniques to ascertain opinion in a relatively unstructured situation was the work of the Research Branch of the Information and Education Division in the War Department in contributing to the development of the point system. The branch was asked to survey soldiers and propose a system which could be predicted to reduce to a minimum the expected complaints with respect to order of discharge, though of course nobody dreamed that all complaints could be eliminated. This study was initiated in the fall of 1943. Here *really* was an unstructured situation. If you asked a soldier back in those days who should get out of the Army early when the war was over, you would have found this was a subject he had not thought about except in terms of himself. Should older men get a preference? Sure. Should combat veterans? Of course. Should fathers? Naturally. And so on through the gamut of categories—except, perhaps, noncoms. The difficulty was that few thought it through far enough to see that if you gave men in *X* category a preference this would penalize category *Y* men relatively, even if *Y* men got some kind of a preference, too. Finally, it was decided to give the men a series of paired comparisons somewhat like the following: Here are two men, Brown and Jones. Both have been overseas two years and both are married. Who should get out first? Brown, who is twenty-five and has been through two campaigns? Or Jones, who is thirty-five but has not been in combat? If the respondent voted

for Brown he voted, in effect, for giving two campaigns preference over ten years of age.

The problem was to reconcile the information, not always consistent, from a series of such comparisons and to construct a series of weights which would, on reapplication to the original comparisons, most closely approximate the men's concrete choices. This involved devising some new mathematical formulations, which are described in a recent issue of the *Annals of Mathematical Statistics.* The point system announced, which was a fairly close practical approximation to what had been derived from an analysis of soldier responses, was initially acclaimed by the press with remarkable unanimity, as shown by an O.W.I. survey of editorial opinion; was approved as fair by about 70 percent of the public, according to a Gallup Poll (just about the same proportion, incidentally, as approved Selective Service); and was approved by about 70 percent of the soldiers. There were some expected howls from families of soldiers who had not been overseas because overseas men got too much credit compared with, say, fathers; and there were even stronger howls from overseas men because combat service was inadequately rewarded in their judgment as compared with, say, fathers. But by the time V–J Day came around two-thirds of the soldiers still approved the point system. As time went on the great anxiety of the soldiers to come home and of the home folks to have them back tended to bring the point system in for more criticism, as its sole function, namely, determining the *priority* of discharge, became confused with *speed* of discharge. But further studies showed that the majority of the soldiers still thought the point system was fair, even though there was mounting dissatisfaction with the speed of demobilization.

Some of those in research who were trying to keep their fingers on the GI pulse after V–E Day are convinced that a priority system which would have opened the gates to widespread favoritism or which would have struck the majority of soldiers as unjust or arbitrary—coming when the pressure for discharge was explosive—might have precipitated a most embarrassing situation for America. How much the recognized justice of the point system helped, we will never know, but I think that mathematical statisticians and social scientists can take satisfaction in the fact that their technical tools were called for and used on a problem of such compelling urgency. Incidentally, a rather nice tribute to the Army's point system was paid by the Marine Corps—which adopted the system without a change. When the Marine Corps imitates the Army, that's something!

These illustrations from research within the government could be multiplied many times from the work of both governmental and nongovernmental research organizations. They show the recognition which has already been given to the necessity of working out carefully the structure of opinion on a given issue, lest the conclusions be misleading. Some recent developments in scale analysis and in the use of an intensity function are particularly promising, though still in the developmental stage. Much work needs to be done on methodology before surveys become as reliable an instrument for measuring and predicting opinion as they someday will become. Much work also needs to be done in reexamining theories of public-opinion formation. Survey techniques will help to test these theories; better theories, in turn, will aid in the analysis of an issue and thus produce more useful survey techniques.

Finally, a few words should be said

about the danger that polls will have too much rather than too little influence on governmental action. I am here speaking about thoroughly good surveys because superficial surveys with sloppily worded questions would have too much influence if they had any influence at all. It is the theory of representative government that the public delegates to its representatives, and that the executive delegates to its experts, a vast amount of technical detail about which the public cannot be expected to have an informed opinion. This is obviously necessary. It is also necessary that government play both a leading and a restraining role with respect to the public. For opinion surveys to develop so much prestige that no official would dare take a stand in the interests of the long-run will of the people when this stand conflicts with the short-run will of the people would be dangerous in the extreme. That day is not yet here, though it may be closer than we think. However, if we have Lincoln's faith in the people, we must not only recognize that the public must be the ultimate judge of the wisdom of its servants, but we must also recognize the necessity of giving the public every opportunity to become an informed judge. Surveys in the years ahead will presumably concentrate less on reporting what the public's off-the-cuff vote is on such a subject as, say, the type of authority which should control atomic energy and more and more on an analysis of how adequately various segments of the public are informed with respect to all the alternatives and how people with different amounts of information or misinformation view the problem in different ways. This helps speedily to bring the facts out into the glare of daylight so that public discussion in the press and radio, the barber shop and the living room, will not be based on obfuscation and myths about what such and such elements of the public want, and so that the leaders of public opinion—on all sides of the issue—can know exactly where their arguments need to be directed if they are to win support.

The social scientists—psychologists, sociologists, economists, aided by mathematical statisticians—feel a certain pride in reporting how tools forged by social science have come to play a role in the affairs of life. I think we are under no illusions. Like the application of the work of a chemist, the applications of new methods of opinion research may have their dangers to society as well as their advantages. We as social scientists have the obligation to make the tools better and better, and we as citizens have the obligation in and out of government to see that these powerful instruments are wisely employed, providing scientific measures to supplement the time-honored contacts between the public and its government. There is no turning back.

These tools can and must be improved and directed to serve their greatest function, namely, informing government and informing the public how thoroughly and with what result various segments of the public have pursued a public issue in the light of alternative contingencies. And by thus helping to improve the channels of communication, social science is making one of its contributions, helping to see to it that government of the people, by the people, and for the people shall not perish from the earth.

SCIENCE AND THE SUPERNATURAL

By ARTHUR H. COMPTON

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THOSE whose thinking is disciplined by science, like all others, need a basis for the good life, for aspiration, for courage to do great deeds. They need a faith to live by. The hope of the world lies in those who have such faith and who use the methods of science to make their visions become real. Such visions and hope and faith are not a part of science. Physics, chemistry, and biology are not concerned with them. They are known by an individual only as he himself experiences them. Though stimulated by the outside world, they are not of it. They are beyond the nature that science knows. Of such is the true "supernatural" that gives meaning to life. This "supernatural" is as real as the natural world of science and is consistent with the most rigorous application of the scientific method.

The "supernatural" specifically denied by Anton Carlson in the August 1944 number of THE SCIENTIFIC MONTHLY is the supernatural of magic, especially events contrary to known natural processes. Carlson has done a real service to those concerned with finding adequate objectives for living in a scientific world by showing the danger that comes from basing our greatest values on evidence that science cannot accept. Science requires of religion that the language in which its great truths have been stated by prophets who lived in an age of magic, miracles, and mysticism be translated into a language of verifiable fact. This lesson our religious leaders must learn, or inevitably with the growth of public reliance on science the effectiveness of their teaching will decline.

Having, however, thus performed a truly Herculean task of cleaning the Augean stables, Carlson steals away with the cattle that the stables would shelter. He denies significance to anything other than physical events, that is, events observable by the senses or measurable by physical instruments. At least it is easy to read this implication into his statement, as is done by Anna Rosenberg (in the November 1944 number of the same journal) in her letter supporting his positivistic position. It is at this point at which probably most American scientists would emphatically part company with Carlson and the positivists.

Though Carlson's discussion shows clearly his interest in the good life, since he denies the supernatural it would be readily inferred that he considers religion as inconsistent with science and inimical to the good life. Whether or not such an inference would be fair to Carlson, it would give a false view of both science and religion.

Let me then give a scientist's view of the fundamentals of religion. The following ideas are taken almost wholly from religious sources whose traditional authenticity is unquestionable. Yet I find no way in which they conflict with the spirit of even Carlson's Spartan science.

I take it that religion is concerned with the worship of God. "God," however, is a word with many meanings. I shall consider three meanings that are of special religious significance: God as the ruler of the universe; God as a hero to be admired and emulated; and God as the spirit of the highest good which serves as the guiding principle of one's life.

Better than at any earlier time we who live in a scientific world can recognize the grandeur of the universe of which we are a part. We have learned many of the laws according to which it works, of the motions of stars and atoms, and something of the evolution of galaxies and of life. What will be our attitude toward this world? Shall we fear what may happen to us, be impassive, or have confidence in what the future will bring? Can our efforts adapt our world to our needs, or must we suppose that an irrevocable fate approaches over which we have no control, so that effort is meaningless?

Science tells us that a well-adapted organism thrives and an ill-adapted one declines and eventually disappears. This may be summarized by saying that on the whole the world is kind to all that live and is especially so to those that learn nature's laws and follow them. Experience shows that we can use the forces of nature to shape our world and that our lives are better or worse according to what type of changes we make.

Jesus has summarized such common experience with the great powers that shape our destinies by the phrase "our Father which art in heaven," or "heavenly Father." By this he implies that these great powers help those who work in accord with their laws. As children in our father's home, we have a proper place in the world. We also can share in shaping the world: "My Father worketh to this end, and I work."

It is helpful to compare such a religious concept with a typical scientific theory; for example, the physicist's theory of the ether. When we pray to our fatherly God it is common experience that we receive courage and strength to do deeds of friendliness toward his children. It is hard to think of receiving strength without imagining a being which gives us the strength. Similarly, by performing certain optical experiments, we find that light has the properties of waves, and it is hard to think of waves without imagining a medium in which the waves can occur. Hence the concept of the "luminiferous ether."

Both the fatherly God and the luminiferous ether are hypotheses which are fruitful of useful consequences. If God is our father, we are his children and other persons become our brothers. We thus have an understandable basis for loving our fellows. When we examine the properties that the ether must have to transmit waves with the speed of light, we find that these properties also fit it to transmit electric and magnetic forces and we have a basis for understanding the relation between electricity and light. If the Ruler of the Universe is as a Father, we can rest assured that he will provide for our basic needs. If space is filled with a medium that has the properties needed for it to transmit electrical waves of light, then we can predict interesting effects produced on light by electrical and magnetic fields, predictions which when tested by Faraday and Kerr are found to be correct.

A scientist gauges the value of a theory by the fruitfulness of its consequences. In judging the worth of religious teachings our highest authority says, "By their fruits ye shall know them." By this test both the theory of the ether and the concept of God as a Father are fruitful of valuable results and hence good.

The rationalist can correctly claim that in neither case do the tests supply valid evidence for the truth of the hypothesis. Is it God that gives us strength or is it our faith that there is a God? Is there indeed a medium that transmits the waves, or is the medium merely an intellectual device for interpreting an observed pattern of optical effects? Physicists recognize that the

"ether" is a convenient name for certain properties of space and that calling it a "medium" gives inaccurate connotations because of our familiarity with solid, liquid, and gaseous media; yet because in terms of this etherial medium it is possible to explain what actually happens, we continue to use the concept. An "etherial medium" is the best brief description of these properties of space that has been invented. It helps our constructive imagination to think of an "ether" in dealing with light and electricity. Similarly, theologians recognize that the use of the term "God" is only a convenient name for certain great powers that operate in nature and particularly in man and that speaking of God as a "father" gives inaccurate connotations because of our tendency to think of all the physiological characteristics of the human fathers that we know. Yet because in terms of this fatherly God we can so accurately describe what actually happens in the normal life of an individual living in a world to which he is adapted, the concept remains very useful and no other brief description of these powers has proved to be so adequate. Thinking of a "fatherly God" thus helps in giving us a correct attitude toward our world.

"Is there a fatherly God?" is a question precisely similar to "Is there an etherial medium?" In both cases the answer is Yes and No. If by "etherial" you mean something mystical or to be found only outside the earth, if by "medium" you mean a solid or a liquid or a gas, there is no "etherial medium" that transmits waves of light. But if by "etherial" you mean the dielectric constant and magnetic permeability appropriate to empty space and if by "medium" you mean that which transmits electromagnetic waves, there is in truth an etherial medium.

Likewise, if by "father" you mean the physiological sire of a child, if by "God" you means a manlike entity that dwells in the space between the stars, there is no "fatherly God." But if by "fatherly" you refer to the friendly, yet disciplinary, aspects of the world that teach you how best to act to meet whatever happens and to be pleased that your experiences make you more of a man, if by "God" you mean the creative and controlling forces at work in the world, then there is indeed a "fatherly God" for all who want to find him.

So MUCH for the concept of God as Ruler of the Universe. Now let us think of God as a hero to be admired and emulated. Our heroes have always been our "gods" who have helped us in shaping our attitudes and actions. We see in our great men the embodiment of some spirit we admire and want to share. I remember how my father reasoned out his own Christian philosophy and used it to fortify and stabilize his life and, trying to follow his footsteps, I become an ancestor worshiper. I have an older brother whose interest and achievement in science have inspired me to do likewise and I have sought and carefully weighed his counsel when facing crucial decisions. The General with whom I was most intimately associated in the effort to win the war has become to me the personification of complete patriotism. He helps me understand the values and the dangers of that great virtue. Anton Carlson I admire because of his devotion to rigorous scientific truth. "Honest Anton," we call him and love him for his courage, though we may deplore his inability to recognize the limitations of science. From earliest childhood I have learned to see in Jesus the supreme example of one who loves his neighbors and expresses that love in actions that count, who knows that people can find their souls by losing themselves in something of great value, who will die rather than deny the truth in favor of

the popular view held by his most respected contemporaries. That Jesus' spirit lives so vitally in men today makes me hope that by following in his footsteps in my small way I also may live forever.

It would do violence to common usage to say, except in the extreme case of the one whom I hold as my supreme example, that these men are my "gods." But it is correct to say that for me they all represent certain aspects of the Divine Spirit, and by knowing them I come to know my God. In particular, Jesus becomes the central figure in exemplifying the ideals that I would like to live by. I admire him, emulate him, and become loyal to him. He becomes my Hero-God.

Yet from the religious point of view, the most fundamental meaning of "God" is neither the Ruler of the Universe nor the Hero after whom one patterns his life. It is rather the "highest good" which one takes as the guiding principle of his life.

I am reminded of the day when Jesus paused to chat with the woman at the well. You recall the setting. "Our fathers worshiped in this mountain," was the woman's comment. "And ye say that in Jerusalem is the place where men ought to worship." "Believe me," replied Jesus, "the hour cometh, and now is, when the true worshipers shall worship the Father in spirit and in truth. God is a spirit; and they that worship him must worship him in spirit and in truth."

If God is what we worship, God is that which we value most highly, to which we would devote our lives. We may worship that God by prayer or by action. Prayer consists in trying to find what our God would have us do. The action is determined on the basis of the answer to that prayer.

Take for example the man whose God is money. The gaining of riches becomes the objective of his life. His sordid prayer becomes the scheming as to how to gain more wealth, and his acquisitiveness is reflected in his every act. Or take the man whose God is the State. He puts its welfare above all other values. He is the patriot who sees the supreme good in the glory of his nation, even at the expense of the rest of the world. The Christian's God is the God of love. "God is love and he whoever continues in love keeps in union with Him and he with God." Perhaps one should explain that by Christian love is meant not a physical passion nor a sentiment of adoration and admiration, but a friendliness that expresses itself in doing good to one's neighbors. Prayer to the God of love means a thoughtful consideration as to how such good can best be done. The action resulting from such a prayer is the highest worship of the God of love. "A religious observance that is pure and stainless in the sight of God the Father is this: to look after orphans and widows in their trouble, and keep one's self unstained by the world."

Jesus is vehement in his insistence that concern with the true worth of things is the one essential without which life really has no value: "Whoever speaks against the Son of Man will be forgiven for it, but whoever speaks against the Holy Spirit cannot be forgiven for it, either in this world or in the world to come." St. Paul in a positive way is equally outspoken: "The spiritual man is alive to all true values, but his own true value no unspiritual man can see."

There is an immense difference between a good religion and a bad religion in the satisfactions and disappointments to which they lead. The main difference is the nature of the values or the kind of spirit that the religion inspires. The true God is the spirit which is found to

be of lasting value, so that when the test comes one can feel that whatever may happen he has spent his life for the best that he knows. The false God is the desire which when attained does not bring satisfaction but makes one feel that he has betrayed or lost something of greater value.

Here is the essence of religion, the pearl of great price for which one sells everything that he has in order that he may own the pearl. One's God is in truth the spirit that inspires his actions —that which gives him the aspiration and purpose—the will to lose himself in something of value. What is that spirit? The Christian answer is, love which shows itself in deeds that help one's fellows.

It remains only to point out that the God of the "highest good" is indeed effective in our lives. As during the recent war we saw the value of freedom, our nation became inspired to the great achievement that brought us victory. Freedom was the great good, the aspect of God, that we sought. I saw one group, determined to stop the Nazi threat against the world's freedom, catch the vision of the new weapon of atomic energy. With faith in that vision and driven by devotion to freedom, they performed the miracle of the atomic bomb. I have seen my friends, worshiping the God of love, catch the vision of a richer life for all mankind and by heroic self-sacrifice bring new hope to people whose lives had held little meaning. I have seen young men and women in college catch the spirit of service for their fellows and do a job far greater than that of their companions who had failed to catch that spirit. And the lives of the latter have been drab, whereas those that have been driven by the spirit of service have had the glowing faces that come with the rich life that money cannot buy. Do we want magic and mysticism, an Aladdin's lamp that will change a peasant's hut into a prince's palace? Here in worship of the God of the spirit of the highest good such magic is truly to be found.

Without saying so, I have outlined here an interpretation of that most abstruse of Christian teachings, the doctrine of the Trinity: God the Father, God the Hero-Son, and God the Spirit. I doubt if even Professor Carlson would take exception to my presentation. For in their essence there can be no conflict between science and religion. Science is a reliable method of finding truth. Religion is the search for a satisfying basis for life.

Every religion builds for itself a structure which goes far beyond the foundation that I have just sketched. It develops its guiding principles using the best thought of the time. Jesus taught in stories of daily life. The later Christian writings were shaped in the combined atmosphere of later Greek philosophy and of oriental magic and mysticism. It was an intellectual atmosphere to which present-day thought is ill adapted. It is of most vital importance that the eternal spirit of religion for which our century cries shall break out of the sarcophagus of the magic formulas in which it is buried and come to vigorous life in our lives.

The breaking of idols is a necessary recurring process. This is done not only in religion. Science also has its Gideons, its John the Baptists, and its Luthers. It was not long ago that Heisenberg told the scientific world,

> The resolution of the paradoxes of atomic physics can be accomplished only by renunciation of old and cherished ideas. Most important of these is the idea that natural phenomena obey exact laws—the principle of causality.

No principle had seemed more precious in science than that of exact laws, and it has gone hard with many old heroes in the field to see the younger men quit the

faith that to them seemed the very foundation of their thinking. Yet the worshipers of this idol are rapidly growing less, and in its place is a spirit of faith in the simplest interpretation of scientific evidence which has given to physics a vigorous new life.

Carlson is concerned with the concepts which for many centuries have served as focusing points for the thought and meditation of millions of faithful religious souls. These concepts have served as our icons and idols; but some of them are now as anachronistic as the golden calf. If our religious leaders are to bring to the present day the vital, living spirit of their faith, they must take Carlson seriously. Science is growing. Yet a world that has science needs as never before the inspiration that religion has to offer. In a strict, literal sense, Carlson is right, that magic and miracles and mysticism are of an outlived era. But the other half of the picture is far more important. Beyond the nature taught by science is the spirit that gives meaning to life.

"So faith, hope and love endure. These are the great three, and the greatest of them is love." This is not science, or nature. It is the true supernatural.

A YULETIDE PRAYER

1945

Prometheus, friend of man, brought heavenly fire,
To kindle hearth and beacon, forge and pyre.
Many his gift for evil uses take—
For war and arson, burnings at the stake.

Revealing Science now the key has gained
To loose primordial force in atoms chained,
Tremendous power, the heartbeat of the world—
Or else destruction's bomb on humans hurled.

Lord, grant that peoples and their leaders see
The greatest good for all humanity,
And use what Science brings into our ken
To hasten peace on earth, good will towards men.

JEROME ALEXANDER

THE HUMMINGBIRDS' BROOK

By ALEXANDER F. SKUTCH
SAN ISIDRO DEL GENERAL, COSTA RICA

When I planted a hedge about my yard, I chose the purple-flowered *Stachytarpheta,* a kind of bushy verbena, not because it forms the primmest of hedges but because of all the hedge shrubs I know it is the most attractive to hummingbirds. The little, short-tubed blossoms form a compact wreath about the middle of the long, naked flower spike, moving upward as the withelike spike continues to grow. If the early part of the year is not too dry, the plant blooms throughout the twelve months and provides a never-failing source of nectar for the flower sprites.

First to discover the earliest blossoms of my newly-planted hedge, and ever since their best patron, was Guimet's Hummingbird, a tiny emerald gem whose head, turned toward the watcher, flashes forth most intense metallic violet. A white spot behind each eye gives him an alert, wide-awake aspect, entirely in keeping with his swift, dashing movements. Suspended between wings vibrating so rapidly as to be invisible, he makes the circuit of the wreath of florets, the tip of his slender black bill probing the heart of each for a single instant, then darts off to a neighboring spike. These glittering bits of animation carry my thoughts back to the Hummingbirds' Brook.

It was hard to stay inside the thick walls of the old museum in San José during those clear, sunny months that started off the year. All around me in the herbarium were cases full of botanical specimens, long since dry and colorless, for which I had recently become responsible. They clamored, as well as such lifeless things may, for care and rearrangement. But the weather of the early *verano,* with its cold, starry nights and warm, sun-flooded days, was like some heady wine. Try as I might, I could not imprison my thoughts within those massive walls of puddled clay, among the herbarium specimens. They persisted in floating out over the surrounding mountains whence, years before, Pittier and Tonduz and Brenes had gathered those same specimens. Through the deep-embrasured windows of the herbarium I could see nothing of those hills, but only a little sunlit rectangle of courtyard where goldfish swam in a pond and a few orchids grew. But climbing the dusty, circling stairway of the old square tower at the end of the building, I could fill my eyes with the sight of the green hills that swept in a wide circle about the narrow plateau where the city stood, calling a naturalist in so many directions at once that his mind became a disordered whirl of enticing and impracticable projects for exploration. In the northeast, seeming very close in the clear morning atmosphere, rose the immense, sprawling bulk of the Volcano Irazú, with a lofty column of smoke arising from its flat summit. Blown southward by the trade wind, this eruptive material spread a fine layer of dust over the glass cases of the museum.

The call of those green hills was too strong to be resisted, especially by one who had so recently forsworn his full liberty to roam them. Many a plant still unknown to science lurked among those forested mountains, so inviting in the distance, but upon actual contact so rugged and forbidding and opposing such formidable obstacles to the progress of puny man. Would it not be well to collect, now in the good weather, samples

of the flora of some hitherto unexplored nook among the mountains? A few thousand new specimens, more or less, to arrange along with the old ones during the long, wet months that would follow could make no great difference. The sympathetic director of the museum readily agreed with these arguments. I was free to take to the hills!

A friend in the southern part of the country wrote that he had found a little house for me in the valley of the Río Pacuar, on a farm adjoining his own. My horse was waiting in his pasture; Efraim, the boy who in past years had cooked for me and carried the plant press, was again willing to serve. The Ministry of Education provided an airplane pass. Leaving the capital before sunrise, the trimotored machine set me down in the village of San Isidro del General in time for breakfast. In little more than half an hour we had passed over a wilderness of forest and mountain which, without wings, we could not have traversed in less than four days of toilsome journeying over rough trails. That same afternoon, my friend Don Juan and I set forth on foot to visit his farm at Santa Rosa and the cabin he had rented for my use. We went slowly, for those afternoons of late February were warm and the road dry and dusty. We were ashamed to count how many times we paused to rest and chat with farmers while we refreshed ourselves with the sweet golden oranges that grew by the roadside. The narrow, winding cartway rose and fell, crossing many a ridge and many a clear stream in the valleys, passing among hillside pastures, strips of forest, and fields where the dry stalks of last year's maize were already all but hidden among the swiftly springing weeds.

At length, as the sun fell lower, we came to the brow of a slope longer than any we had left behind. Far below, the tree-bordered channel of the Pacuar meandered through verdant, shady pastures, amid which stood, here and there, low, rough farmhouses roofed with dull-red tiles. Beyond the valley the coastal range rose up, summit behind summit, all clad in a dark green mantle of forest. The steep hills were notched by wooded gorges, whose cool, shadowed depths stood out in dark contrast to the intervening ridges aglow in the sunshine. In the north rose the rounded bosses of El Cerro de la Muerte, huge and grim and gray, and the other lofty summits of the Talamancan Cordillera. What a scene it made!—the deep, narrow valley with its quiet dwellings set in the bright green of pastures and cultivation like "a haunt of ancient peace" in the midst of those wild hills.

Near the foot of the long slope we entered Don Juan's pasture, caught and saddled our horses, and resumed our journey on four feet instead of two. By a broad, shallow ford we rode across the Pacuar, passed over a level pasture, then forded the rocky bed of the Río San Antonio. On a shelf cut into the steep hillside above this stream stood the house I was to occupy. It was of the usual type and soon inspected: a narrow porch across the front; opening onto this, two small, square rooms to serve as living room and kitchen; two tiny, rectangular cubicles under the sloping roof at the rear to be used as bedrooms. In the kitchen were some shelves and a wooden platform covered with clay upon which to make a fire, the smoke escaping as best it might; in one of the bedrooms, a wooden bedstead with hard boards instead of springs; in the *sala,* or living room, a rickety table, a pair of stools without backs, and a great heap of maize ears piled up in a corner. The roof was of unglazed tiles, the walls of rough, unpainted boards, partly papered over on the interior with old newspapers boldly announcing patented remedies for the most intimate maladies.

Not a palatial nor even a homelike dwelling, certainly; but with a few cooking utensils and a folding canvas cot—enough, with the collecting apparatus and some staple supplies, to fill an oxcart—it would make an exceptionally comfortable camp. If there were no pictures save the cartoons in the yellowing newspapers to relieve the drabness of the walls, it was only necessary to throw open the wooden shutters that closed the glassless windows to enjoy a diorama painted with master strokes on the grandest scale. In the foreground spread level pastures, shaded by slender, stately *ojoche* trees nearly fifty yards high. In the midst of the meadows, two lines of lower trees, converging into one line at the right, indicated the point of confluence of the Pacuar and San Antonio rivers. Beyond, the mountains rose up, crest above forested crest, to the bare, treeless summit of El Cerro de la Muerte; and the long ridges of the continental divide, with their ever-changing masses of cloud, closed off the prospect to the north.

Locking up the vacant cottage, we mounted our horses to ride up the ridge that rose sharply behind it. A hundred yards from the dwelling the forest began like a wall, forty yards high. As we neared its edge, a small bird with spotless white plumage flew out from a treetop and swung in a long catenary curve across the valley to the hanging forest on the farther side. It was my first Antonia's Snowy Cotinga (*Carpodectes nitidus antoniae*). I looked upon it as an augury for a prosperous season.

Two days later we moved into our little cabin. Efraim made up the fire and put the beans and rice on to boil; Bayon grazed contentedly in the pasture at the side; I unpacked and set up the apparatus for drying the botanical specimens. In a day or so we had settled down to a routine. Arising at daybreak, we breakfasted as the sun's first rays struck up the valley, dissolving the silvery mists that had gathered during the night. Almost every morning at sunrise, a flock of Little Blue Herons (*Florida caerulea*), four adults in slate-blue plumage and eleven young birds clad in purest white, winged deliberately up the river, following every winding of the tree-shaded channel and holding our gaze enthralled until they vanished around a curve. At sunset they returned down the valley. Later I found where they roosted, on leafy boughs overhanging the channel.

While the sun was still low above the crests of the forest, we locked up the cabin and set forth on the day's excursion, with lunch in the knapsack and the plant press full of papers for the specimens. No matter where a man lives, he soon finds a favorite walk which attracts him beyond all others and of which he never tires. So it was with us. There were few roads or even clean paths in the immediate neighborhood, but the course of the Río San Antonio became our highway. We drank from and bathed in its waters, and it led us back among the hills into haunts of unsuspected beauty. It was an enchanting stream. Its current, filtered through scarcely broken forests, was always clear. Even when swollen with the heavy rains of May and June, it never became brown and turbid like the Pacuar, which flowed through a cleared and cultivated valley and when in flood formed a sharp contrast with the limpid tributary stream. During the nearly rainless months of February and March both rivers were low and gentle, and the smaller San Antonio could at many points be crossed dry-shod on steppingstones.

First we explored the lower portion of the stream, where it flowed through the pastures. Here and there it slipped over a rock to form a low, murmurous cascade, but there were no falls of any great height. The channel was shaded by

trees, chiefly the gnarled *sotecaballo*, or riverwood (*Pithecolobium*), whose long boughs reached far over the channel and in places completely overarched it, forming a dark, cool retreat never penetrated by the hot midday sun. Verdant masses of the river *Cuphea*, a shrubby relative of the humble clammy herb of northern fields, covered the rocks that rose above the water; and on the portions of these rocks recently left dry by the falling current, innumerable tiny brown seed pods of the Podostemonaceae, no bigger than the moss capsules for which they are sometimes mistaken, stood up on their short, threadlike brown stalks. Feathery green fronds of the same delicate water herbs—which include some of the very smallest of all flowering plants—waved in the flowing water where they grew attached to portions of the rocks still submerged. At the end of February a climber of the bignonia family spread a profusion of pretty pink trumpet blossoms over the lower branches of the riverside trees; and later another woody vine (*Securidaca*), an aspiring relative of the little northern milkwort, displayed in the treetops dense masses of small, two-winged, pealike blossoms, forming delightful expanses of pinkish-lavender color.

Where the twisted riverwood trees cast the deepest shade over the water and were most heavily burdened with an aerial garden of orchids, ferns, bromeliads, and other air plants (displaying here in the open air a collection of conservatory plants which for the variety and magnificence of its specimens would make any northern florist turn green with envy) a slender log formed a footbridge from shore to shore. The slippery upper face of the log had been only slightly flattened with the axe, and one wearing shoes found it prudent to support himself with a long pole as he passed over. Beneath this rustic bridge, the current, which just above had passed turbulently along a boulder-strewn reach of the channel, flowed smooth and deep over great, dark, flat rock strata of gentle inclination, locally called *lajas*. Later, when the flood waters carried the log away, we could scarcely leave our secluded camp save by fording the swollen current on horseback or else making a long and difficult detour down the river.

Above the still waters by the footbridge, a Royal Flycatcher (*Onychorhynchus mexicanus*) hung her yard-long nest of brown fibers; here where no boisterous wind could roll the two brown eggs from the shallow niche in the middle of the tangled mass that so little resembled a bird's nest. Only on the rarest and most memorable of occasions did she or her mate spread fanwise their high, scarlet diadems, which transformed a pair of dull, olive-colored birds with low topknots into superb creatures of regal distinction. Here, too, lived a pair of Buff-rumped Warblers (*Basileuterus fulvicauda*), perpetually wagging their dark-tipped, pale yellow tails as they foraged along the shore and over the rocks in the channel. The male sang a ringing crescendo, loud, mellow, and jubilant; and from time to time his mate replied in a full-toned warble so beautiful that, no less than the music of Orpheus, it seemed to possess the power to "draw iron tears down Pluto's cheek." In April this happy pair, working side by side to the accompaniment of their flowing song, built their domed nest upon a fern-shaded rock on the bank of the stream; but some creature broke up the nest before the two spotted eggs could hatch.

One morning in April, as we crossed the footbridge, a small animal clambered up the underside of the thick trunk of a great riverwood tree. Climbing backdownward along the inclined trunk until it reached some erect branches, it easily scrambled up among the foliage, where it stopped in full view. It was a kinka-

jou (*Potos flavus*), a relative of the raccoon and the coatimundi, about the size of the former but more slender and shorter-legged, and everywhere, including its long, gracefully curving tail, clothed with brownish-gray fur that appeared very thick and soft. Despite the low, flattened crown, its little face was attractive and appealing, with its short, blunt, black muzzle, large dark eyes, and little ears set far down on the sides of the head and expressively mobile. I have sometimes seen that puckish, somnolent face thrust sleepily from the doorway of a hole made by one of the large woodpeckers, or out of a small natural cavity, in a trunk where my taps had aroused the beastie from its day-long slumbers.

But this particular kinkajou preferred on a warm afternoon to take its siesta among the open boughs. Disregarding two human spectators, the animal settled itself comfortably among the branches and began to wash its fur with its tongue, which was remarkably long and slender. It seemed very sleepy, for it frequently interrupted its licking to yawn, extruding its pink tongue to an amazing length. It continued alternately to yawn and lazily lick its pelage until we grew tired of watching. Returning at intervals through the afternoon, I found the kinkajou slumbering in various comfortable positions, once resting back downward in a crotch, its head bent forward and resting on its abdomen, its arms thrown over the neighboring branches for support, its feet in the air. When aroused, it yawned with sleepy indifference and promptly resumed its slumbers.

An hour after nightfall, when day had dawned for it, I found the kinkajou moving away among the uppermost boughs of the riverwood tree, doubtless to breakfast upon the fruits of neighboring trees. Its eyes shone with intense brilliance in the beam of my electric torch. I wish that I could have followed as it moved off through the dusky foliage, to learn more of its ways. What a pity that so many of our fellow-mammals are children of the night, going about the business of living under the cover of darkness and remaining stranger to us than the birds, which are not so close of kin. Even the crepuscular Pauraque (*Nyctidromus albicollis*) that drowsed all day beneath the thicket at the edge of the pasture, venturing forth in the twilight to sound its clear, plaintive cries, was more companionable than most of the wild four-footed animals among which we dwelt.

From the pastures we gradually extended our explorations along the upper reaches of the river. The number of specimens to be gathered made it impossible to cover a great distance on any single day; but each day we penetrated a little farther into the mountain fastnesses. Now we were no longer able to walk easily over the meadows by the riverside and found it simplest to make our way along the bed of the stream itself, stepping or jumping laboriously from rock to rock or from ledge to ledge, often crossing from one side to the other to take advantage of the rocks closest together. But sometimes, where deep pools extended from shore to shore, we were obliged to leave the channel and with our long machetes cut a path through the undergrowth at the forest's edge.

At most points the slopes rose up steeply from the brink of the stream. They were covered with lofty forest trees that met above the narrowing channel and cast a deep shade over its waters. In February, a tall shrub of the acanthus family, a species of *Aphelandra*, displayed glowing masses of scarlet blossoms in the rather open glades along the river. But aside from this attractive shrub, which soon passed from bloom, there was, as usual, scarcely any color in the undergrowth of the forest. The

course of the stream itself was slightly more colorful. At times during the brighter hours of the day, a wide-winged Morpho butterfly traced its swift, erratic course above the channel, flashing glints of the most intense azure. Other brilliant butterflies were not absent; and there were gigantic dragonflies whose long wings were of glassy transparency and colorless save for a small rectangle of deep blue at the tip of each. Over the rocks in and beside the river and on the foliage along the banks rested bright-colored little frogs, seldom much over an inch in length, boldly marked with black and green and—on the larger specimens—red. These were sluggish creatures and, unlike the majority of batrachians, exceedingly reluctant to remove themselves from beneath human feet. At best they would creep slowly out of our way, so that often they owed their lives more to our own care in placing our steps than to any praiseworthy efforts of their own. We forbore to touch these showy frogs, for they are said to be poisonous. Their excessive abundance and their indifference to concealment, in a region where even inconspicuous green and brown frogs are careful to hide themselves from the many frog-eating birds and reptiles, made me confident that we had here a genuine example of warning coloration.

The rocks along the stream were overgrown with delicate ferns of great beauty. A low herb with modest white flowers (*Spigelia humboldtiana*) blossomed on ledges where a little soil had accumulated. Great boulders whose tops stood well above the water level supported profuse overgrowths of plants, including a tall, glossy-leafed begonia with white flowers and clusias with fleshy foliage and fragrant white blossoms. On an islet we found a splendid shrubby *Columnea*, whose long, furry leaves, red over most of the lower surface, were spread out fanwise and completely sheltered the slender, tubular, red corollas. I had never before seen this beautiful plant; nor, apparently, had any other botanist, for in Washington it was declared to be of a species new to science.

During most of the day a profound silence reigned along this forest waterway; the only habitual sounds were the soft murmur of the falling waters and the loud buzzing of the great cicadas among the trees. These noises were so continuously in our ears that we soon lost consciousness of them; they formed the background against which less constant sounds stood out. Among these were the loud, sweet songs of the Buff-rumped Warblers or, more rarely, the clear, ringing notes of the bay-backed River Wren, which dwelt here where the stream flowed through the forest as well as along the bushy margins of its course through the clearings. Now and again the short, compelling whistles of the Wood Wren rang out of the forest. Seldom, indeed, at this season, did we hear the voice of some other bird such as the exquisitely modulated whistles of the Chestnut-headed Tinamou. But on the morning when we frightened a pair of Crested Guans passing with half-grown young through the treetops, we had no lack of loud, excited calls, high-pitched and weak for such big, long-tailed fowl, the size of a hen turkey.

Continuing up the main stream, we reached a portion of the channel which was, if possible, still more beautiful than that we already knew. The river here followed the dip of the strata of the massive dark gray rock of which those hills were so largely built; but its descent was more gradual than the inclination of the rock layers. Thus each stratum exposed its edge to the erosive action of the stream. The soft layers had been worn away, leaving pools held back by the hard layers. Some of these pools were wide and deep, each brimful of the clearest water, which slipped over the lip to flow down a long, even incline to

another pool below. In places there were abrupt falls, but there were also long reaches of nearly level channel, strewn with great, irregular rocks. Here and there low cliffs, draped with verdure, rose from the water's edge. Everywhere the great trees of the forest stood along both banks and cast their shade over the hurrying, dancing waters. In the inmost recesses of this mountain forest the world and its bustling activity seemed infinitely remote; yet at times even here our thoughts were abruptly recalled to it by the hum of an airplane passing unseen above the treetops on its way from San Isidro to one of the little coastal towns.

As we laboriously worked our way up the rough, difficult watercourse, Efraim espied on the rocks ahead a bird such as neither of us had ever beheld. It was a fairly big, stout-bodied fowl, with long legs, long slender neck, and a sharp, straight bill of moderate length. In form it somewhat resembled a heron or bittern, but in coloration it was quite different from members of these families, and its relatively much longer tail set it apart from them at a glance. Its colors were rather subdued: black on the head, brown on the neck, maroon-brown on the breast, dark gray on the back and closed wings, white on the throat and abdomen, and nearly everywhere barred, spotted, or streaked with black and white. Its eyes were deep red, and its long legs, naked to well above the knee joint, bright orange.

Such was the appearance of the strange bird as it walked deliberately over the steeply inclined rock face between two pools, plucking certain small objects from the rocks washed by the smoothly-flowing rapids. We had watched it for many minutes, attracted by its rareness rather than its beauty, when it slipped on the smooth wet rock and, half-opening its wings to balance itself, dazzled us with a glimpse of unsuspected splendor. As it flitted from boulder to boulder, it continued to reveal tantalizing flashes of hidden beauty. But only when the bird spread its wings broadly for a longer flight did it display their full magnificence. On each was a big, round shield of deep orange-chestnut, set in the midst of an area of much paler orange-buff—a sun darkly glowing in a sunset-tinted sky. There was also a second patch of orange-chestnut near the tip of each wing. When I saw those lovely wings painted with the image of the sun, I had no doubt that I had my first Sun-Bittern (*Eurypyga helias*) before me. Like that other denizen of these forest waterways, the Royal Flycatcher, this rare bird kept its proudest ornament concealed most of the time.

The most important affluent of the Río San Antonio from the right was a rocky streamlet hemmed in by steep, forested slopes, so narrow that at many points we could leap from bank to bank. But it also had its picturesque cascades and shared the wild beauty of the river to which it delivered up its unsullied waters. Along this narrow watercourse we discovered more birds' nests than along the broader stream. Here, in the still air, attached to the long, dangling, cordlike roots of epiphytic plants or to slender pendent vines and shoots of climbing bamboo, hung the exquisite nests of the little olive-green flycatcher called Pipromorpha. Each nest was a pear-shaped structure a foot in length, covered with green moss; a small round doorway in the side led into a cozy chamber well padded with vegetable fibers. In an even more conspicuous position above the channel, the Myiobius, a brisk little forest flycatcher with a bright yellow rump, had constructed her nest, a thin-walled pocket of brown fibers, with a visor-like projection shielding the round doorway in the side.

Most abundant along the watercourse, although also most difficult to detect,

were the nests of the Guimet's Hummingbirds (*Klais guimeti*), each a tiny chalice of green moss, softly lined with seed down of a light buffy color and fastened by spider's silk to slender, usually drooping, leafy branches overhanging the channel, at heights of from three to twelve feet above the water. Without making a thorough search, we found three of these nests along the Río San Antonio and five along the smaller affluent, making eight occupied nests along two or three miles of waterway. There were perhaps as many more empty ones, of which we kept no accurate count. Early March is the height of the breeding season, and the nests might contain anything from two minute, elongate white eggs newly laid to feathered nestlings almost ready to fly. But there were never more than two eggs or nestlings in a nest. Because it is so unusual to find hummingbirds' nests in such abundance in the lowland forest (I have rarely seen more than three or four in a year) we decided to name the stream above which they hung *La Quebrada de los Gorriónes,* "The Hummingbirds' Brook."

After several hours of leisurely progress along the rocky bed of the brook, we halted for lunch in a spot of rare beauty. A steeply sloping ramp of naked gray rock rose in the stream bed before us between low, vertical cliffs. Down this incline the shrunken current of March flowed in two separate streams, one against the right base of the cliff in a long, even trough; the other, with a low waterfall in its course, made a broken and precipitous descent on the left. At the foot of the twin cataracts, the waters were reunited in a broad pool, nearly square in outline, about forty feet on a side, and deep enough to swim in. But only a naiad could have entered its pellucid depths without seeming to defile them. We left them in their unruffled serenity, to mirror the broad, infinitely subdivided fronds of a cluster of tree ferns that grew at the brink, surrounded by exuberant verdure and deeply shaded by the giants of the forest.

Climbing the tongue of rock between the cataracts, we found two more nests of the hummingbird, only forty feet apart. One, in a bush leaning over the falling water halfway up, held two eggs; the second, on a moss-covered pendulous branch of a small tree at the head of the waterfall, cradled two feathered nestlings. It was surprising to find these two occupied nests of the same species of hummingbird so close together; but as we continued along the course of the brook above the cataracts, we made a discovery still more astonishing. A richly branched bush, leaning far out over the narrow channel, almost blocked our way. As we pushed past, we espied another nest of the same kind, attached to a slender pendent branch, only three feet and three inches—almost exactly one meter—above the water. This nest was unusually tall, as though it had been built atop an older one—as hummingbirds' nests sometimes are—and it held two eggs. Four feet away in the same bush and fifteen inches higher above the water, was yet another nest, from which a well-feathered fledgling took flight as we approached. After a short pursuit, I captured the young fugitive and returned it beside its nestmate, where rather unexpectedly it was good enough to remain.

Hummingbirds are generally held to be unsociable. Certainly they lack the true convivial spirit that inspires such flocking birds as crows, grackles, and cormorants; and except in their courtship assemblies, where they exhibit a certain degree of community enterprise even in rivalry, it is every hummer for himself. Even male and female form no lasting attachments, and the latter always attends her nest and nestlings

quite alone. Hence the discovery of two hummingbird's nests in the same small bush was a memorable event, calling for further study. But the day was already far spent; and since it would be folly to try to move along that broken stream bed in the black dark that would prevail an hour after sunset, we were obliged to hurry downward before daylight forsook us.

Next morning I laboriously retraced my steps along the stream. I had already proved at other nests that if I sat quietly on a rock at no great distance, the hummingbirds would soon return to attend their eggs or nestlings. I seated myself on a rounded boulder, from which I commanded a good view of the two nests. The well-feathered nestlings in the one nearer me were bright, alert little sprites, who frequently preened their plumage and from time to time beat their wings into a haze, the while anchoring themselves to the bottom of the nest with their feet lest they be carried away by these vigorous exercises. When an adult of their kind came within sight, they were all alertness, uttering clear little droplets of sound in anticipation of good things to eat. Apparently they were unable to distinguish their mother from her neighbor, for they called in the same fashion at the approach of either. But the incubating hummer, each time she arrived, went directly to sit upon her own eggs, paying no attention to the other's family. The two fledglings had the gray throat of their mother rather than the deep violet of the adult male, as did all others of their age that we found.

The owners of these two nests, upon returning from an excursion into the forest, would sometimes approach me closely, hovering only a yard or two from my face while they subjected me to close scrutiny. Then, apparently satisfied that this strange monster that spied upon them was not to be dreaded, they went to their nests. Or, again, after feeding her nestlings, the mother of the two would approach to look me over once more before darting off. At a nest farther downstream, a hummingbird flew up to feed her babies, apparently without having noticed that during her absence I had seated myself near by. While she was in the midst of regurgitating food to them, my sudden movement in raising the binoculars for a closer view attracted her attention. At once interrupting the nestlings' meal, she darted up to examine her visitor in the usual fashion. Then she returned to plunge her sharp bill far down into a nestling's throat and continue the process of feeding, making me feel that I had created a favorable impression and my presence was not distasteful to her. These and many other examinations to which I have been subjected by hummingbirds of varied kinds appeared to be deliberate and purposeful acts, prompted in some instances by simple curiosity and in others by concern for the safety of their nests and offspring. They suggest that hummingbirds may be somewhat nearsighted, which is not surprising when one considers the minute size of the nests they build and of the insects they pluck from the vegetation or snatch from the air.

On approaching her nest, each hummingbird would alternately dart and hover, shooting a short distance now to this side and now to that, irregularly back and forth, at the end of each abrupt shift of position hanging stationary for an instant, on swiftly beating wings. Then of a sudden the tiny bird would plop down upon her eggs with her wings already folded against her sides, or alight upon the rim of the little cup to thrust her slender black bill far down into the crop of a fledgling and begin to pump nourishment into it. The hummingbird with eggs seemed a trifle fearful of her neighbor with nestlings, for

on two occasions she suddenly flew away as the other came to attend them. Once she continued to sit while the young birds received their meal, only to dart away as her neighbor was leaving.

No violet-throated male appeared on the scene; in fact, I never saw a single male Guimet's Hummingbird anywhere along the stream. At this season the more brilliant sex was to be found on sunny perches near the edge of the forest, each bird sounding his metallic little voice through all the long, bright day and interrupting his animated but tuneless song only to moisten his throat at the inexhaustible fount of the flowers. Often four or five of the Guimet's Hummingbirds sang close together, but each on his own perch, to which he returned after every brief absence. So the males let the other sex know that they waited to woo them; but never once did they give assistance in the care of the nest.

While seated on the boulder watching the two nests above the forest stream, I was assailed by that uncomfortable feeling I sometimes experience in the woods, of being myself watched by unseen eyes. Suddenly, a long black snake, mottled with yellow, glided down an oblique ledge of the cliff on my right. It moved rapidly without a pause until it came to rest on a rock in midstream, almost beneath the two nestlings. There it lay motionless with its head lifted high, looking up at the young hummingbirds and without much doubt considering in dull serpentine fashion how it could reach them. Knowing from repeated unhappy experiences the insatiable appetite of the mica (*Spilotes pullatus*) for eggs and nestlings, I resolved to remove all possibility of tragedy. A snake intent upon ravin appears to become insensible to everything else, at times even to mortal wounds. This one was no exception to the rule and lingered immobile while I approached and delivered the stroke that sent it writhing madly into the water, where the current bore it slowly down the stream to die.

Feeling that the hummingbirds were safe for the moment, I continued upstream until I found my way blocked by a wall of rock ten feet high, stretching transversely across the channel. At this point the current was divided into two separate falls, like Niagara in miniature. That on the right dropped with a single leap into a deep, shady recess in the rock. The left branch babbled down among great loose boulders, beneath a huge block of rock which, wedged between the central pier of stone and the high cliff that formed the left wall of the ravine, made a natural bridge over the cascade. Like most of the wider rocks above the reach of the flood waters, this bridge was profusely overgrown with begonias, aroids, clusias, and other plants. I was obliged to crawl beneath this verdant rock bridge in order to gain the top of the wall that obstructed the channel. Passing under the bridge, I almost brushed against a neat little nest that hung above the cascade. It was attached to a splinter beneath the butt of a huge shattered tree trunk lying in the stream bed above. The nest was of pyriform shape with a round entrance in the side, shielded by a visor-like projection; its walls were composed almost wholly of fibrous rootlets and the interior amply lined with light-colored bast fibers finely shredded and some tufts of silky seed down. In this cozy retreat so excellently concealed rested a single pin-feathered nestling, which cried shrilly when I illuminated its nursery with a small electric bulb and looked in with a tiny mirror.

I could not even guess who the maker and owner of this ingeniously hidden nest might be and sat upon the central pier of rock to await her approach. After an hour a tiny flycatcher (*Leptopogon superciliaris*), gray and olive-green and pale yellow, arrived with a small green

tree cricket in her bill. Nervous and shy, she approached and left her nest by darting beneath the bridge of rock, thereby making it still more difficult for hostile eyes to follow her movements. Yet she fed the nestling while I rested in plain view only ten feet off—three feedings in as many hours.

Of a sudden as I watched I was startled by loud, shrill cries rising out of the deep recess at my right, into which more than half the flow of the stream leapt down in a single unbroken fall. Leaning over the overhanging wall of rock, I peered into the obscurity of the chasm without being able to discern more than rock and water—nothing that could possibly utter such earsplitting cries. But the shrill notes continued; so I descended by way of the gentler cascade on the other side, beneath the bridging rock, crept along the base of the abrupt wall, and peered into the recess from the front. There, on the wet, slippery, overhanging face of rock behind the falling water, clung two big, black swifts with narrow white collars. Crying loudly, at short intervals they fluttered from one point on the rock to another. Their hurried movements and sharp cries suggested great excitement. All at once they brushed past me, rose through the narrow chasm between the tree trunks that marked the course of the brook, and vanished into the illimitable vastness above. Nor did they return during the next hour. Numberless times I had watched great flocks of these largest of Central American swifts wheeling with shrill cries far overhead but never before had I come so close to them. They are said to nest in crannies in cliffs and possibly, like the Black Swift, they sometimes attach their nests behind a waterfall. Removing shoes and socks, I waded into the alcove behind the falls (not without a wetting) but could find no indication of a nest nor any cranny that might have supported one. Probably these White-collared Swifts (*Streptoprocne zonaris*) were disappointed in their quest for a nest site, as I, upon my return a fortnight later, was disappointed in my desire to learn something about their home life.

The afternoon was now more than half spent, and I turned homeward, to make sure of reaching the clearing before it grew dark. I was climbing down the long ramp of rock above the big pool, passing over a narrow and slippery ledge in the cataract on its left side and thinking how unpleasant it would be to meet, in that insecure position, the huge snake that had left its slough upon the neighboring slope, when a creature of quite a different character appeared. A hummingbird flew out of the forest and clung to the inclined rock surface over which the water poured in a thin sheet, almost at my feet. First he appeared to drink, then bathed, pushing his head down into the flowing water, shaking his wings, and wetting himself all over. He was big for a hummingbird and had a long, straight, black bill and a deeply forked, black tail. His upper plumage was green; and I caught shifting glints of intense, metallic blue from his throat. He quite ignored my presence, even when to save myself from falling I shifted my position. Then he brushed past to perch in a low bush close behind me, shake the water from his plumage, and put it in order. Before I could maneuver myself into a position to view him favorably in the dim light, he was gone, unidentified in the terms of science, yet ever to be identified in memory with this beautiful cataract in the course of an enchanting sylvan stream. Thenceforth, the highest fall on the Hummingbirds' Brook was known as the "Hummingbird Cascades."

ART CHEMISTRY

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When the Roman poet Horace in a moment of exaltation asserted that his poems would outlast bronze, he was not so far wrong after all. Because more than poetry or music, which may be preserved by oral tradition, art is dependent on matter, and many works of art have been lost forever because the material from which they have been made has decayed with time or has been destroyed altogether. This is particularly the case where unsuitable material or a wrong technique has been employed.

There are innumerable instances of deteriorated or lost works of art. All that we know of classical Greek painting are names of artists and descriptions of some of their principal works in the handbook for travelers in Greece by Pausanias. From Polygnotus, Apollodorus, Parrhasius, Nicias, or Aristeides not a picture has survived. Their works were executed in the archaic technique of encaustic. The pigments were mixed with beeswax, and the mixture applied with hot bronze tools to wooden boards. Another method was to lay on the molten wax, mixed with the pigment, with a brush. As both beeswax and wood are rather frail materials, it is no wonder that nothing has survived the ages.

Many statues of the early Middle Ages in Western and Middle Europe, especially on the outside of buildings, have become defaced because they were cut from sandstone that easily weathers away.

A similar fate befell some of the works of Leonardo da Vinci. His famous painting "The Last Supper" in the refectory of the former Dominican convent, Santa Maria delle Grazie, in Milan, considered by many one of the best works of medieval art, is now practically lost. In order to avoid the difficulties connected with the fresco technique, where the picture has to be finished while the freshly plastered wall is still damp, he used the tempera technique, where the pigments are mixed with egg yolk and applied on a specially prepared wall surface. This gave him the opportunity to work slowly and carefully, but the technique itself was entirely unsuitable for a wall painting in the damp Lombardian climate. The artist himself lived to see the doom of his best painting. That only wrong technique was the cause of the loss of this picture becomes obvious from the fact that in the same room some fresco paintings made about the same time by an obscure Italian painter remained perfectly fresh. Another work of art by Leonardo da Vinci, a colossal statue of Lodovico Moro made from specially prepared clay, was entirely lost during the lifetime of the artist.

Many students of art have wondered about the chiaroscuro of old Dutch paintings, especially those by Rembrandt. Chiaroscuro is a manner of painting where the faces of personages are represented as high lights on an utterly dark background. The effect is only partly due to the intention of the artist himself; it is much more a sign of deterioration of the picture. The Dutch painters used white lead liberally in their paintings. This produced a marvelous paint but one apt to darken with time and become almost black. For the faces they did not use this paint which explains the present state of the pictures.

Unsuitable painting material caused

much damage in the nineteenth century. With the rapid advance of science and the discovery of new materials, painters came to use pigments before their durability was thoroughly established. Makart, a Viennese painter very popular in the 1880's, achieved very pretty effects by using a solution of asphalt in oil as a warm brown paint. Asphalt, however, darkens with time even faster than does white lead, with the result that some of his pictures had to be withdrawn from the museum because they grew so dark. The aniline dyes, beautiful and brilliant at first, deteriorate the other way around. They bleach in the light, and many paintings painted in the last quarter of the nineteenth century are now faded out or are almost blank.

These works of art are owned only by museums and rich people, but there is another instance of deterioration that affects practically everyone. I mean the decay of engravings and old books. Booklovers all over the world note with regret the deterioration of books even in the short span of a human life. It was not always so. Books written on vellum many centuries ago are still in perfect condition; books printed two or three hundred years ago are still in good condition; whereas books printed only a few decades ago often fall to pieces between the fingers of the reader. Bruce Lockhard lectured some years ago on the theme, "Will books survive?" Considering what I have just said, we might repeat his question from an entirely different point of view. Rossiter Johnson wrote in 1891 that "centuries hence some bibliographer will construct an ingenious theory to explain why no books were printed between 1870 and 19—, the date at which we accomplish the destruction of the forests and begin again on cotton."

Why has modern paper such low durability as compared with paper made from rags a hundred and fifty or more years ago? The first reason is that wood pulp is used in the manufacture of paper Wood contains a substance called lignin, which withers easily and causes the paper to become yellow and brittle in a few years. As practically all newspapers are printed on such paper, complicated methods for preservation have been devised, since newspapers are stored in libraries as valuable material for future historians. One method consists in pasting sheets of transparent Japan paper on both sides of the newspaper sheet—a very expensive method indeed, for the conservation of an ordinary daily paper in this way would amount to several hundred dollars a year. The other reason for the low durability of modern papers is the careless use of bleaching chemicals. In order to get perfectly white paper, the pulp has to be bleached. If, after bleaching, the chemicals are not carefully washed out and the paper is sized with resin (an ordinary procedure to make paper stronger and less permeable for ink), it will become brittle and brown in a short time even if it is made from rags.

Paper can be damaged in other ways, too. There are first of all insects that eat their way through books or, rather, through the bindings of books. There are few books over three hundred years old which do not show traces of insects having been busy with them. Another, still greater, nuisance is the so-called foxing of paper. The ugly rusty spots that appear on many books and engravings, especially if kept in dark, damp rooms, were formerly ascribed to insects, but Pierre See proved in 1919 beyond doubt that the damage is caused by different kinds of mildew. Later investigations carried out in England have shown that only paper that contains traces of iron gets foxy. The question of foxing on books and engravings has become particularly acute in the past few years. In case of war, books and other

works of art have to be stored in cellars for protection against air raids, and such places are very likely to be both dark and damp. In the first World War pastels by Maurice-Quentin de La Tour owned by the local museum in St. Quentin had to be stored in a cellar, and some of them got badly and irreparably foxy.

From the examples just mentioned, we see the importance of the durability of the material for the survival of works of art. One of the first tasks of art chemistry is therefore the investigation of durability of materials used in art.

ANOTHER interesting chapter in art chemistry is the rediscovery of lost techniques. There are many instances where techniques used for many years have been entirely lost.

The art of making dark red glass, exercised by the Romans and Byzantines, was lost in the early Middle Ages, to be rediscovered by the German alchemist Kunkel about 1680. The art of making Egyptian blue, a beautiful blue pigment consisting of a calcium-copper silicate known in Egypt from the Sixth Dynasty, was lost between the second and seventh century of our era. To make this blue, sand was mixed with copper carbonate, lime, and a little soda and kept at a temperature between 800° C. and 900° C. for about twenty-four hours. Below 800° C. the blue is not formed, and above 900° C. a green glass is obtained, so the temperature has to be carefully regulated. Another lost art was the use of the beautiful crimson pigment prepared from Murex. It was the privilege of royalty to wear garments dyed with that dye, and it was only in the nineteenth century that the procedure was rediscovered. In the 1870's Schliemann discovered in Mycenae gold vessels dating from about 1000 B.C. with a remarkable velvet luster that could not be duplicated by any modern art. It was only a few years ago that an English jeweler rediscovered the technique. He applied gold dust under water with a brush to a gold surface coated with solder and subsequently heated the object till the solder melted.

There are lost arts that have not so far been rediscovered. Petronius Arbiter tells the story of an artisan who in the reign of Emperor Tiberius discovered malleable glass. He showed a vessel made from this glass to the emperor and then threw it on the floor. The vessel got dented but did not break. The artisan then took a hammer and repaired the vessel. The emperor became fearful lest gold and silver would lose their value and asked the artisan whether he had disclosed his secret to anyone. Though the artisan denied this, the emperor ordered his execution to stamp out such a dangerous invention. This story is also mentioned by Pliny. Although we have now a series of flexible, transparent, organic substances that are widely used, the art of making malleable glass has not been rediscovered. Another lost art is the making of malleable bronze, supposed to have been known in some countries three thousand years before our era and never known since.

The third task of art chemistry is the investigation of the genuineness of art objects and the discovery of frauds. As art objects sometimes achieve very high prices, the incentive for falsification is great. A thorough chemical analysis in many cases will show the fraud. Pictures where aniline dyes were used cannot have been painted before 1870. Another possibility is the determination of the refractive index of linseed oil used in the preparation of oil paints. A. P. Laurie has shown that the index increases in eight days from 1.480 to 1.494; in one year to 1.500; in three years to 1.512. The refractive index of linseed oil used in a painting from the fourteenth century was 1.600. Thus we can roughly date a picture by the refractive index of

its oil paint. A direct consequence of the increase of the refractive index is the fact that oil paints get duller and more translucent with age. In cases where one oil painting is made over another one, the underpainting ultimately shows through. An interesting example is a picture by Pieter de Hooch in the National Gallery in London where the floor tiles show through the dress of a woman standing by the fireplace.

Recently infrared, ultraviolet, and Roentgen rays furnished new possibilities for investigation of pictures and of the materials from which they are made. We can also determine whether some parts of the picture have been covered later by paint. Some years ago a French painter made an excellent copy of a painting by Tizian and signed the painting with his name as the copyist. The art dealer who bought the picture, wanting to sell it as an original, covered the signature of the copyist with oil paint and substituted Tizian's initials. The prospective customer, however, was cautious enough to have the picture investigated by Roentgen rays. The photograph clearly showed the signature of the French copyist.

The fourth field of art chemistry is the art of preserving and restoring works of art. In this field great advances have been made in the past fifty years. This is especially the case with objects made of metal, bronze, or iron. In former days it was customary to clean such metal objects that were covered with rust mechanically, using sand; or chemically, using acids. Important parts of the object have been lost in this way. Nowadays weak electric currents are used to reduce the metal oxides to metal again. The art object is placed as a cathode in a solution of sodium carbonate or sodium hydroxide and a very weak electric current passed through for days. In the case of bronze objects some results have been quite surprising. Coins that had practically become lumps of oxide returned to their former shape, and all the inscriptions on them became easily readable. Small statues, completely disfigured, revealed their hidden beauties again. (It is regrettable that some of the best formulas for the electrolytic restoration of bronzes are still kept secret by various experts in this field.) Small iron objects can be freed from oxide without loss of substance by placing them for fifteen minutes in molten potassium cyanide.

More complicated is the restoration of old pictures. Before starting it is necessary to know what material has been used in painting. Then the picture is cleaned. Pictures darkened with time can be made lighter if the darkening is due to white lead. Hydrogen peroxide will turn black lead sulfide to white lead sulfate and clear the colors. Asphalt, however, cannot be bleached, and cases where the darkening of a picture is due to asphalt are incurable.

Then there is the problem of foxy papers. Various formulas have been tried to prevent or stop foxing or to bleach foxy spots. Douglas Cockerell suggested an alcoholic solution of thymol, a substance sometimes used in dentistry, to stop foxing. The paper is dipped in the solution, or the solution is applied with a brush. The method is not very satisfactory, as thymol is a rather weak antiseptic. W. Haslam recommends chloride of lime instead. This is a powerful antiseptic that will not only kill the mildew, but will at the same time bleach the paper and restore it to its former whiteness. It has one disadvantage: it leaves free chlorine behind, which might destroy the paper if not carefully removed. Still others have suggested sulfur dioxide, easily obtained by burning sulfur. This is a very effective, but for the paper, extremely dangerous, substance, as it yields sulfuric acid, which in time will destroy the

paper altogether. After some experiment I have developed a formula that is a little cumbersome but which gives very satisfactory results: the paper is first put in a solution of potassium oxalate to remove traces of iron, if present; afterwards it is left for twelve hours in a 2 percent solution of chloramine, a substance used in World War I for disinfecting wounds, washed with a solution of sodium thiosulfate, then with water, sized with a warm 2 percent solution of gelatin, and then dried between sheets of white blotting paper. This method can be used to repair foxy books or engravings, but the books have to be taken apart and rebound after the procedure.

In the case of pictures, also, mildew may result from storage in dark, damp places. During the war many paintings from the Madrid museums suffered this kind of damage after being stored in cellars. A quick method of preventing foxing is therefore essential, and here, too, some new methods have been developed. New, extremely powerful, but otherwise perfectly harmless, disinfectants can be used. One method is to mix thoroughly one part of benzylester of paraoxybenzoic acid with three parts of talcum and apply the fine white powder with a brush so thinly that only an invisible layer is left. This white powder is almost insoluble in water and about eighty times as powerful as carbolic acid, itself a very strong antiseptic. It can be used to prevent the formation of mildew on furniture and books as well as on paintings.

Finally, there is the problem of the preservation and restoration of leather, particularly bookbindings. Any visitor to public libraries will have noticed the deplorable state of some bookbindings, especially of books that are very seldom used. Even here leather manufactured a century ago has shown itself stronger and more resistant than modern leathers. In 1858 a discussion was held at the Royal Society of Arts in London on the durability of leather bindings, in which it was pointed out that leather bindings appear to resist dampness better than extreme dryness. For some time the heat from gas lamps was considered responsible for the damage, but Douglas Cockerell pointed out the same damage in the British Museum Library where no gas was used. The main trouble, however, seems to lie in the indiscriminate use of strong chemicals, even of sulfuric acid, in the modern preparation of the leather. To prevent damage to bookbindings various authors have recommended a thin coating of shellac, vaseline, or of mixtures of oil and wax.

IN ACCENTUATION OF THE NEGATIVE

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THE times make opportune some re-examination of mankind's moral maxims. Reference is not mainly to war, wholesale denier of liberty, but to something more normal and retail—peacetime denials of man's will-to-independence. It is notorious that in the latest doctoring of the dictionary, "liberalism" has changed its meaning from *laissez faire* to "let us legislate"; and one may observe that there is abroad in the world the determination for many to become most meanly their brothers' keepers. We shall speak of these matters at the easy level of popular symbolism—"gold," "silver," "aluminum"—but our thought runs deeper: the danger of moral prescriptions; the fear of a new age of faith and solicitude; the hope of a political order which will maintain between men such social distance as can effectively discourage infliction of the will-to-power in the name of the will-to-perfection.

THE DOWNWARD CLIMAX OF RULES

The Golden Rule. Throughout Christendom there is available a directive for life which takes the form of law but which at the same time is supposed to loosen the rigor of the ethical absolute. "Do unto others as you would have others do unto you." In high testimonial, this has been named the "Golden Rule." It is really two rules, and we must consider its elements separately. The first element of the injunction is "do." It clearly enjoins action—and action with reference to others. It elevates into supreme importance the distinction between self and others but it seems to plump at once for altruism as the essence of obligation. We are our brothers' keepers; we are not good if detached; we veritably belong to one another; we must find the meaning of living in life's other-regarding aspect. Giving rather than getting becomes the *sine qua non* of morality. So it seems at first glance but not so completely so on second thought.

Further reflection, indeed, fixes attention on a less obvious element in the rule, an element which mitigates the rigor of pure altruism. It advertises the self as a point of departure and as the point of return. It tells us what it is that we owe a debt to *do*. We must do something to and for others, but what we owe to do is determined out of respect to what we ourselves can approve when we are on the receiving end of action. What we must do to others is indeed just what we ourselves would like if others did it to us. To apply the rule, one must first understand himself, must first respect himself, must indeed affirm himself as the standard. A rule of thoroughgoing altruism would prescribe *doing unto others as others would have us do unto them.* The altruism of the Golden Rule is made to depend upon egoism; but egoism is made to operate only in a social milieu.

Familiar enough are the difficulties adduced against the categorical imperative thus modified. They arise from the fact that a rule which seems prima facie social is ultima facie self-centered. The paradox is mitigated only by presuming a situation in which this conflict is antecedently resolved by prevailing usage. That is, the rule holds unparadoxically only between equals who are culturally like-minded. My friend, for instance, buys me a season ticket for grand opera when to grand opera I am more than insensitive; I am downright antipathetic.

My friend does this to me because, perhaps without thinking much about it, he would appreciate such a gift from me. But on the same principle a grand opera ticket would be the last gift I should think of offering him. His gift is a burden to me, and even an irritation. To the irritation he has often replied that I *ought* to like grand opera whether I do or not. He thinks that all that is required to educate me in the right direction is sufficient exposure of me to operatic exquisiteness. My friend and I are equals; otherwise we would not be friends and not be exchanging gifts. But we are not like-minded. Neither's personality is a good reference point for the other, *save upon the assumption of interventionism as the meaning of obligation.* There indeed is the rub. If we enhance the unlike-mindedness, this moral rule rendered possible by friendship will then obtrude so conspicuously as to become downright intolerable.

As a standard test, consider the savage chieftain who offered the Christian missionary a harem of the tribe's most seductive maidens. The chieftain did not understand the missionary's protest. Had he not been taught the Golden Rule by the missionary? Would he not himself expect this courtesy if he visited the missionary in the Christain homeland? The missionary could make his declination stick only by first getting overtly accepted what is the covert assumption of the rule, that he and the chieftain are not equals. The chieftain must first renounce his preferences *in favor of* those of the missionary before they can facilitate friendly intercourse on the basis of the Golden Rule.

Now this noble impartiality of self-preference, which appears to underlie the rule, not only involves an antidemocratic element but it also thinly disguises prejudice against variety as the juice of life. Men must agree upon "fundamentals," and the agreement must be in the spirit of "you and I is one, but I is de one." You can afford altruism only after altruism has, through self-reference, veered toward egoism—and then has perhaps forgotten what it has become through the operation of external factors making for sameness. The root of the defect which begins to emerge from this analysis is not so much egoism as it is interventionism. There is a lingering suspicion of priggishness in the operation of any principle which makes it the duty of one man *to do* anything to another man. "The most priggish business in the world," observed Woodrow Wilson, "is the development of one's character." Especially is this so when one seeks his own fulfillment in "doing good." Wilson should have known.

The Silver Rule. A rule which thus tends to abolish itself by passing into its opposite—other-reference here passing into self-reference—requires mitigation if it is to escape discard. Let us seek mitigation from the Golden Rule in consideration of what has been called the Silver Rule. Instead of "do" we now, with Plato and Confucius, substitute "don't do." *Don't do unto others what you would not have them do unto you.* This is clearly further from enjoining personal interventionism than is the former as a rule of life. It seems indeed to affirm the very opposite. On second thought, however, it is doubtful whether it goes so far as that. Instead of being broken up into two elements, like the first rule, this injunction hangs together as an organic unity. It does not in its most natural sense mean (1) "don't" with (2) a positive elaboration; you don't elaborate a downright negative. And yet there follows an elaboration of the "don't." So, as a matter of simple fact, the inner meaning of this "don't" is also somehow corrupted with the notion of "do."

To put it so as to bring out both the unity and the positive element: "Don't do to others what you don't want done to

you." We actually get thus as its latent meaning, "Do something other than what you don't want done to you." The Silver Rule, negative in form, is, in part at least, positive in sense, with a caution *about* interventionism rather than a forthright imperative *against* it. Interventionism with caution, it seems to imply, is better than interventionism without restraint. But interventionism is interference, however safeguarded. So if we are to seek the major positive meaning of our quest for a lessening rigor of rules, we must further mitigate what we seem not easily able to exorcise altogether.

The Aluminum Rule. Suppose we change this emphasis as nearly altogether as is possible in rule-making. Let us regard interventionism as an evil rather than a good, even though up to some point an inevitable evil. Then we would get a rule reading something like this: *Don't let others do to you what you wouldn't do to them.* This doubles the distance from interventionism by doubling the negative against it. Since it lightens the obligation of action and reserves a field for personal liberty, I have called it the "Aluminum Rule," as befits free man's passion for lightness. Aluminum is late of date, light by nature, and durable in usage.

The articulation of such a rule budges the rule-making impulse toward if not to its minimum; it saves the impulse but lightens its burden as much as is humanly possible. It does this from the thought that the burden of interventionism is more than any man can carry with modest grace. There is an animal impulse, a deep human undertow, which drives us on to make, as the poet's clairvoyance has it, "easy simplicity of lives not our own." But that this impulse is worthy of being made a part of the obligation of man is soundly to be doubted. In the spirit of a great predecessor we ask: If men cannot govern themselves, how in heaven's name can they be thought to govern one another? Men who have become masters of themselves seem always to lack much of the common drive to manage other people's lives. Indeed, a man who looks out for himself without harm to others probably becomes in so doing author of more good than the man who substitutes for independence *from*, interventionism *in*, the affairs of others.

Nevertheless, it is not enough to make a positive rule to this effect: *Let each man look after himself.* This is not enough because both the animal impetus which we have mentioned and the social tradition giving moral respectability to the impetus urge men to look after each other. Egoism is indeed thought to be morally neutral, if not downright vicious; only altruism is praised as virtuous in the copybook maxims of mankind. Since it is thus, it behooves us, if we see the matter so, to make our supreme rule the injunction of self-protection against the long-prevailing respectability of interventionism. But we have been assuming or, at best, insinuating that positive moral injunctions are bad. Let us now argue the case of abstention so that our Aluminum Rule may emerge, if emerge it can, into the light of a more liberal and loose-jointed respectability.

Upon the Wings of Negativity

Our preference for the negative has more to it than appears. It is in fact a drift from the lesser toward the greater source of value. We would indeed wean men away from nuzzling one another so that they might the better nurse their own well-being. All self-conscious civilization deplores the emphasis upon the external and glorifies the internal. The literal is lethal; only spirit produces spirituality. Now another is always external to one; not as external as sticks and stones, but not as inward as one is to himself. Those who do us the greater wrong are they who think they understand us better than we understand our-

selves. Where completest understanding is, there is man's greatest treasure.

To seek the measure of our morality in ministering to the external, that is to achieve immorality, however fondly we may caress it. Hàving such morality in mind, we ask with Santayana,

> Is not morality a worse enemy of spirit than immorality? Is it not more hopelessly deceptive and entangling? Those romantic poets, for instance, whose lives were often so irregular—were they not evidently far more spiritual than the good people whom they shocked?

Santayana details this latter query: Can anyone now doubt that Shelley was better than the English judge who denied him custody of his own children? Men who command their own souls and both explore and exploit their treasure—are they not always better than men who command the souls of others, wilting and withering what at the best is exotic to their full understanding?

To find the meaning of life in altruism is to locate significance in the extension rather than in the essence of value. It is not in what we *do* but in what we *are* that the first layer of value lies. To be let alone is, by this very fact, the first law of axiology. It is indeed the hidden behest which informs the genius of the American constitutional system. In the Bill of Rights the Fathers "conferred," as Justice Brandeis said in a great decision, "as against the Government, the right to be let alone—the most comprehensive of rights and the right most valued by civilized men." Not only of our Constitution but of our laws as well is this the strong continuing inner spirit. Law is normally in the negative; at least democratic law is. *You shall not do thus and so; and if you do, then this is the penalty.* Such is the spirit of the safest law. It is indeed the business of law "to hinder the hindrances," "to hurt the hurters," "to restrain the restrainers." Be it not cramped, life realizes its greatest boon, to express itself. Intervention can be justified only where it contravenes the interveners. Such circumspection leaves men free to discover and to disclose in self-expression whatever meaning life has found in itself.

Shall morality be less generous and clairvoyant of spirituality than is law? The law, which, as Hobbes said, "is the public conscience," is largely negative in form because it is positive in intent. Shall moralists be turned loose where lawgivers and policemen circumvently if not reverently stay their hands? It is often so; but such morality turns into immorality through the very irreverence of its operation. It becomes gossip and prying and prudery; it becomes the kiss of death upon the budding bloom of life. No man is wise enough to tell man what to do. Positivity is infinite, even in presumption; negativity alone is limited. "Civilization," as Justice Holmes sagely observed, "consists in imposing limits upon the infinite." To undertake positive surveillance of other life is, in the nature of the case, to impoverish your own life with an immodesty which at the same time knocks other lives in the head at the narrows through which they must pass inspection. As initiative must be left to the positive, so negation must fall upon the negative alone.

Two Pilgrims in the Strategy of Negativity

It was the great Jefferson who early in our national history rendered this view of moral negativity sacrosanct, illustrating long before Alfred North Whitehead the latter's insight that "religion is what a man does with his solitariness." Jefferson had suffered, and that continuously, from the attacks of intolerant clergy and the tongues of prying prudes over what they supposed to be his religious heresies. They said that he was an enemy of Christianity and a traitor to the high trust of spiritual leadership. They said that he was an infidel, yea that he was an atheist; that he was a puller-down of temples which housed those more

reverent than he. Jefferson did not reply, continuously he did not reply. Upon solicitation at last from those whose intimacy permitted inquiry, Jefferson at length gave private voice to the faith that was in him. It was not too radical a faith. Indeed, it was so reminiscent of what always passed for Christian conviction, purged of superstition, that his friends besought him to make public what he believed about religion. This he would not do. They implored him to let *them* make public his beliefs, that the mouths of doubters might be stopped and the cries of enemies against him be silenced. Nor would Jefferson permit this. His friends did not understand his reticence, deepening into what they thought stubbornness, as touching what seemed to them his just and adequate defense against persecution.

To their troubled insistence Jefferson at last gave immortal reply. To one he said, "You press me to consent to the publication of my sentiments and suppose they might have effect even on sectarian bigotry. But have they not the Gospel?" To another he wrote, "No, my dear Sir, not for the world. . . . I should as soon undertake to bring the crazy skulls of Bedlam to sound understanding." And, though he submitted that he was "a Christian in the only sense in which *He* wished anyone to be," Jefferson gave to the world, as to his detractors, a refusal of right which is still radiant with wisdom:

> It behooves every man who values liberty of conscience for himself. . . . to give no example of concession, betraying the common right of independent opinion, by answering questions of faith, which the laws have left between God and himself.

Plainly and simply, Jefferson refused, and taught us to refuse, to answer questions that nobody has a right to ask. Any and every interventionism is an evil; and even when it is a necessary evil, it should be kept on the defensive.

Does this seem thorny and crabbed, the attitude which Jefferson portrayed and inculcated? Were we in heaven, Yes; since we are on earth, No. For earth our final wisdom is the Rule of Aluminum, and aluminum can be brittle as well as bright. *Don't let others do to you—even ask of you—what you would not do to, ask of, them.* This is the wisdom of Monticello. Jefferson is our first pilgrim upon this shining way of negativity. Keeping clear always the line between conduct and spirit, Jefferson adds finality to religious negativity: "It does me no injury for my neighbor to say there are twenty gods, or no god. It neither picks my pocket nor breaks my leg." Such clarity of concept and such courage of conviction constitute man's final protection *against* interventionism and the final protection *for* full self-possession of life's plainest dignity and surest values.

It remained for Jefferson not only to refuse by example to set seal upon the most Peep-Tom puerility of the morality of respectability, but for him also to make clear what is the root of his reticence. The trouble is that mankind's best are not intent upon power but rather are content with the pursuit of perfection. Now power is of the outer, but perfection is of the inner, life alone. Those who find only urgency where there ought to be essence will then prod other men, even though these others be engaged in the silent business of communing with perfection. It is the will-to-power which sees morality in personal intervention. It may be called by the noblest names but it remains always identifiable as someone's push for power. Jefferson lacked this will-to-power. Other men who had it would meddle with him; he who would not meddle would not countenance meddling. Not only did he assure his friend Dr. Rush that he considered religion "as a matter between every man and his maker, in which no other, and far less the public, had a right to meddle"; but he put the root matter before

another friend, De Tracy, in these words potent with final explanation of his attitude: "I have been unable to conceive how any rational being could propose happiness to himself from the exercise of power over others."

Jane Addams is our other pilgrim upon this way. In the estimation of her most understanding biographer, James Weber Linn, her nephew, she arrived early at this same exquisite insight: that doing good must not become "do-goodism." She had visited Tolstoy and imbibed whatever of his spirit she could take. Coming home to Hull House, she found herself frustrated, in things external, by West Side Chicago politicians. She set about to defeat the alderman of her district; and into the enterprise, as was her wont, she poured time, energy, and money. She awakened from the plunge in externalism to discover that the politician had "beaten her to a frazzle." Her friends expected her to come back, renew the struggle, and keep at it until the ward was hers. This she did not do. To their surprise she replied that she was giving up the contest. And to their greater surprise she gave as reason for her withdrawal from the contest that the politician had taught her a most valuable lesson, the lesson that he understood the people of Hull-House district better than did she. Among other things, she meant that he was not meddling in their mores. Out of gratitude she was disposed to work with him rather than against him henceforth. The relation thus defined on solid inner foundations of mutual understanding and respectful abstention was a long and fruitful one, not unbeautiful as her biographer unfolds it through the years.

So far as understanding is the main thing—and is there limit to its merit?—the internal's the thing in the life of value. The greater negativity we can achieve against man's urge to intermeddle with man, the more positive the efflorescence of the spirit. That is the law which underlies all law. Such a law has as its overt witness some such attitude as we have sought to present in the Aluminum Rule. The negativity of our formulation will not obscure its contribution to the affirmative life of the spirit.

The truth is that we start with a thousand and one interventions in the name of morality. Moreover, if as animals we did not already start with them, we should soon achieve them in the medley of social living. Men are forever in conflict, each pursuing his interests across the line that intersects the others' orbits. These interests-in-conflict enmantle themselves in moral principles, and the result is that men are ever and anon impaling the conscience of others upon the bayonets of their own. Man's fullest perfection is forever being crucified upon the cross of power. Since man's will-to-power, which each must somehow exemplify in order to live at all, drives us across one another's bailiwicks, our only salvation is some guarantee that the will-to-perfection will find sanctuary in the lapse. The symbol of this lapse is the reluctance to intervene in one another's lives even in the name of conscience. That reluctance is, however, so often victim of the deep undertow to make principle coincident with interest that we need whatever support we can achieve of its superior virtue. Whatever rule can dramatize the superiority of the negative in the strategy of the spirit is useful and right. That is all we have here tried to do; and that, if done, is enough.

Our Reign of Rules in Résumé

Beneficent as the negative is in the life of the spirit, it requires no monopoly. Each rule reigns in proper turn. The Golden Rule has its utility in groups which if not always small are nevertheless like-minded. Now, since every life has its nexus of little loyalties, the rule is wisdom where it is realizable in mutuality. Its relevance is measured by the

limits of like-mindedness. Its best locus is perhaps the family: parents to children—like-minded but unequal. I was about to say that its virtue lies in its being a prod to universalize like-mindedness. That would be, however, to fall into the error to which moral motivation is peculiarly susceptible. The larger truth is not only that universal like-mindedness is impossible but also that it would be of less value than the variety constituted by unlike-mindedness. The value here involved is protected by the natural fact that beyond a point we cannot perpetrate what we ought not of interventionism. Power tends to limit itself by the counteraggression which it provokes.

Where perfection fails of protection from this principle, another rule comes to succor value. Since we cannot extend even our "golden" provinciality unto universality, the Silver Rule is in extension more "golden" than the Golden Rule. Where positive concern turns through social distance into psychic indifference, we water down our urgency into the Silver Rule of moderated interventionism. Not to do to others what we would not have them do to us is to invest with proper moral meaning the natural indifference men feel toward those beyond their borders and toward the unlike-minded within those borders.

Within our national borders we have, through our emphasis upon the Bill of Rights, achieved the right to be alone without too much waving of our aluminum principle. And beyond our borders we have become masters in large part of our ancient will-to-intervene. Distance, physical or psychic, has relieved us of our own will-to-invade. Unfortunately, others have not grown with us into moral neutrality. Against them as a rule of life we need something more tough than silver or gold. Literal aluminum in the earth must be matched by a pertinacity of spirit which we have symbolized as aluminum in the soul. So long as their bellicosity threatens to arise again, we find the apotheosis of honor in the rule that they shall not do to us what we would not do to them. Whoever would in such plight substitute a better rule than this will find himself exemplifying a worse one. When tolerance meets the savagery of interventionism, impulses of vengeance may prove most wholesome as defenses. Better to liquidate such enemies than be liquidated by them.

The last reliance of human dignity is the maintenance of some such attitude as this negative one. The Aluminum Rule transcends in utility every dictate of interventionism and so supplants in universality both the Silver and Golden Rules of life. Who loses this aluminum protection loses both his silver and gold; and who saves his life in habilaments dishonorable loses all that life's about. Not even the like-minded are privileged to violate this rule, though since they will not ordinarily wish to violate it, its tyranny over them is mild. The unlike-minded whom we tolerate cannot step over this line, but, since they will not within our borders ordinarily insist upon violating our privacy, they need little feel the brittle of this rule of exclusion. Should either so far forget friendship or civility as to stoop to "mauling," the rule rises to defend the integrity of the spirit against those who forget the true vocation of man. When those from beyond the pale make bold to ride through the outer defenses of tolerance, then of civility, and then of friendliness, this rule constitutes the final bulwark of integrity against invasion. It is the spirit's last ditch against dishonor and so the first principle of a philosophy of life which reinforces wisdom with courage. It is not the paradoxical law "that there shall be *no* law," but the wisdom that there shall be for us no *alien* law.

ATOMIC AND MOLECULAR ENERGIES*

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THE period of modern physics, which began with Roentgen's discovery of the X-ray fifty years ago, is unique in the history of science. Never before have so many fundamental discoveries been made in the span of half a century. Never since Copernicus have scientists been compelled so thoroughly to admit the limitations of even their basic ideas and adopt new modes of thought in order to comprehend essentially new phenomena. Since the recognition of this aspect of modern physics may well serve as a valuable guide in our search for a proper attitude toward the difficult political problem which has recently been created by atomic scientists, it will be stressed in the present discussion.

The exploration of atomic and molecular structure has been the primary concern of physicists during the past fifty years, and a major part of their efforts has been directed toward the study of atomic and molecular energies. The concept of energy, now regarded as basic and indispensable in every one of the natural sciences, took shape very slowly in mechanics, which next to descriptive astronomy is the oldest part of physical science. In classical mechanics the energy concept is not absolutely essential, and it is derived from other concepts which are regarded as more fundamental. Only in the formulation of mechanics given by Hamilton about a hundred years ago does the idea of energy play a central role.

In the early part of the nineteenth century the desire to improve the steam engine led to various efforts to understand the nature of heat and to discover the relation between heat and mechanical work. In the 1840's Mayer and Helmholtz in Germany, Colding in Denmark, and Joule in England independently arrived at the principle of the conservation of energy.

It may be of interest to note that the first to formulate this principle, Robert Mayer, was led to his discovery by a biological observation. When serving as a ship's doctor he noticed at the harbor of Surabaya in 1840 that the venous blood of the Javanese was almost as bright red as the arterial blood. This, he assumed, was because a smaller amount of oxidation is required to maintain the body temperature in the tropics than in colder climates. Two years later he announced the law of the conservation of energy, but he had great difficulty in getting his paper published and did not live to see his ideas accepted.

The principle of the conservation of energy claims that in all the changes which occur in nature there is something that remains constant, the energy. If energy of one kind disappears an equivalent amount of other forms of energy makes its appearance. Thus, when a gas is compressed at constant temperature, an amount of heat flows away from it which is equal to the work of compression. If the gas is prevented from giving off heat, its temperature goes up when it is compressed, and its so-called internal energy is increased by an amount equal to the work done.

The study of the internal energy and the closely related heat content of substances and of the changes occurring in these quantities with changes in temperature, volume, state of aggregation,

* Part of a public address delivered December 7, 1945, under the auspices of the Oklahoma Academy of Science.

chemical composition, and so on has become a very important field of research.

When the concept of energy is extended to new phenomena, the procedure is always to search for a quantity which makes its appearance when energy of known forms disappears. Thus, the definition of energy depends essentially upon the law of the conservation of energy. For a long time it was believed that all forms of energy are really mechanical in nature; in particular, the internal energy of a body was regarded as mechanical energy of the randomly moving molecules of which the body was believed to be composed.

However, as the study of the electromagnetic phenomena progressed, it was found that the principle of the conservation of energy could be upheld only by assuming that energy resides in the space surrounding electrically charged bodies. It was also found necessary to ascribe momentum to the electromagnetic field, even in empty space. When a charged particle moves with constant velocity the energy in the field simply moves along with the particle. However, classical theory predicts that when the velocity of the particle varies, electromagnetic energy should be radiated with the speed of light. It is perhaps clear that the application of the ideas of energy and momentum to the electromagnetic phenomena required a renunciation of the intuitive character of these concepts, which now took on a broader meaning and ceased to be purely mechanical concepts.

The theory of relativity led to a revision of classical mechanics and to a modified expression for the kinetic energy of a moving body. Moreover, by combining the conservation laws for energy and momentum with the principle of relativity, Einstein was led to the startling conclusion that all energy has inertia, or mass, which can be computed by dividing the energy by the square of the speed of light. Since this is a very large number—nine followed by twenty zeros if c.g.s. units are used—the mass associated with ordinary amounts of energy is usually far too small to be detected.

But if all energy has mass the question naturally arises whether all mass is not a manifestation of energy. If that were true even a small amount of mass would represent an enormous amount of energy; for to convert mass into energy we would have to multiply by nine followed by twenty zeros. Thus, one pound of any material would represent a latent energy of over ten billion kilowatt-hours.

Einstein's theory does not tell how to transform mass into energy nor even claim that such transformation is possible. Rather, it states that if any process exists in which mass is substantially reduced, then the latent energy represented by the lost mass will make its appearance as other forms of energy. When Einstein published his purely theoretical paper forty years ago no means of effecting such a release of energy was in sight. However, his bold idea stirred the imagination of physicists and guided them to remarkable discoveries, the most recent of which is now shaking the world.

The old conception that all matter is made up of a huge number of minute particles became a scientific hypothesis at the beginning of the nineteenth century in the hands of the English physician John Dalton. While many physicists, especially those who were under the influence of Kant's philosophy, still clung to the view that matter is a continuum, Dalton's assumption that chemical compounds are composed of molecules, which in turn are made up of atoms, led to great advances in chemistry. Curiously enough, toward the end of the nineteenth century many chemists,

led by Ostwald, were ready to drop the atomistic view as one which was not absolutely indispensable and which could never be verified experimentally. However, by this time the idea had taken hold among physicists, and they were already carrying out experiments which not only established the existence of atoms beyond any doubt but even gave information about the still smaller particles of which atoms are built up.

The first subatomic particle, the electron, or quantum of negative electricity, was discovered by J. J. Thomson in 1897. Immediately afterwards Lorentz, through his explanation of the magneto-optic effect discovered a year previously by Zeeman, obtained strong evidence for the belief that electrons vibrating inside the atoms are responsible for the emission and absorption of light. However, all attempts to account for the spectra emitted by the elements, on the basis of classical mechanics and electrodynamics, failed. Similarly, Rayleigh's formula for the intensity distribution in the continuous spectrum emitted by a black body, which agreed very closely with the experimental data at long wave lengths, failed completely at short wave lengths. No flaw could be found in Rayleigh's derivation. Thus, it became apparent that atomic phenomena are not governed by the laws of classical physics, which had been regarded by physicists and certain philosophers as having universal validity.

THE gradual renunciation of many of the basic ideas of classical physics and the successful search for new principles leading to an understanding of the atomic phenomena began in the year 1900 when the German physicist Max Planck, in order to obtain a formula for the intensity distribution in the black body radiation, reluctantly made the radical assumption that atoms do not emit or absorb electromagnetic energy continuously but intermittently, in quanta which are proportional to the frequency.

Since the black body radiation depends only upon the temperature and not at all upon the chemical composition of the black body, Planck's theory could give no information about the structure of atoms. However, in 1911 Rutherford discovered that the entire positive charge and practically all the mass of an atom are concentrated in a nucleus having a diameter about ten thousand times as small as the over-all diameter of the atom. Two years later Niels Bohr, making even greater departures from classical physics than had Planck, created his famous quantum theory of atomic structure and spectral lines. This theory was extremely fruitful for more than a decade and led to a remarkably detailed knowledge of the systems of electrons which surround the nuclei of the different chemical elements. In spite of the many successes of the Bohr theory, it gradually became clear that even this theory was not radical enough. However, by 1927 Heisenberg, De Broglie, Schrödinger, Bohr, and others had succeeded in working out a new theory, the so-called quantum mechanics, which provides an adequate basis for the understanding of practically all the known atomic and molecular phenomena. The difficulty which most people experience in grasping this theory is caused by the fact that it requires them to give up some of the ideals which classical physics strove to attain and to learn to use such concepts as energy and momentum in a strange new manner.

As first realized by Bohr, an atom or a molecule can exist more or less permanently only in certain states which are characterized by definite energy values. An atom in a state of high energy may spontaneously undergo a

transition to a stationary state of lower energy. In this process, which cannot be subdivided and hence cannot be described in detail, a rearrangement occurs in the motions of the electrons revolving around the nucleus, and electromagnetic radiation is emitted having a frequency which is proportional to the difference between the energies in the initial and the final state. If an atom in the lower energy state is illuminated by light of this same frequency the reverse transition may occur, that is, light energy may be absorbed and the atom raised to the higher energy level. Thus, when the frequencies emitted or absorbed by a substance are measured by means of a spectrometer, it is possible to determine the energy values in which its atoms or molecules can exist. In some cases thousands of energy levels have been measured.

When an atom is known to be in a given stationary state, no description in terms of time can be given of the electrons within the atom. Any observation of the time when an electron inside an atom passes a certain position would throw the atom over into another stationary state. Thus, it is impossible in principle to follow the path of an electron inside an atom. We must therefore shape our thinking about atoms in such a manner that we are not led to form intuitive pictures about the electronic motions. Furthermore, since any observation of an electron in an atom leads to a break in the causal chain, we are forced to forego a causal description and be satisfied with statistical laws for the atomic phenomena.

Under these circumstances it is remarkable that the principles of the conservation of energy and momentum have been found to hold for all known atomic processes. Several times during the development of the atomic theory phenomena have been discovered which seemed to violate the conservation laws, but further investigation always led to the validation of these laws. It should be pointed out, however, that to uphold the principles of the conservation of energy and momentum it has been necessary to create the idea of light quanta, or photons, and to assume the existence of a particle, the so-called neutrino, which is not directly observable.

Except for the lowest, most stable, state the energy values of atoms and molecules in stationary states are not absolutely sharp. Rather, the width of an energy level is proportional to the probability that the atom will spontaneously jump to any of the lower energy levels in unit time. This follows directly from Heisenberg's famous uncertainty principle.

The energies that we have referred to here are the kinetic and potential energies of electrons and, in the case of molecules, the energies associated with vibrations and rotations of the molecule. The forces involved are essentially the electrostatic attractions between electrons and nuclei and the mutual repulsions between electrons and between nuclei. These are also the forces which bind atoms together to form molecules and bind molecules together in liquids or solids. These statements should not be taken too literally; for, in quantum theory, energy is a basic concept and the idea of force is not used. Moreover, the potential and kinetic energy functions are used in a purely formal manner, and many aspects of atomic or molecular energy, such as the so-called exchange, or resonance, energy which plays an important role in present-day theoretical chemistry, have no counterparts in classical physics. The strangeness of the quantum theory, from the classical point of view, should not surprise us; for the very existence of stable atoms and molecules with well-defined proper-

ties is entirely incomprehensible on the basis of classical ideas.

From spectroscopic measurement of atomic and molecular energies much important information can be derived about the structure of atoms and molecules, about the energy required to break up molecules in different ways, about the energy liberated in chemical reactions, and so on. If a sufficient number of the lower energy values are known for a molecule and if it is known how many stationary states correspond to each of these energy values, it is possible to compute not only the internal energy of the compound in the gaseous state but also the entropy. This important quantity, which measures the degree of disorder, can be used to determine the direction in which a given process, such as a chemical reaction, can go under given circumstances.

Two examples will indicate the magnitude of the energy values which we have to deal with. A silver atom has 47 electrons. It requires only 7.6 electron volts to remove the very outermost electron from the atom but it takes 25,000 electron volts to pull out one of the two electrons which are closest to the nucleus. By an electron volt is meant the energy acquired by an electron when it falls through a potential difference of one volt.

When one molecule of methane unites with two molecules of oxygen in a gas furnace, 9.2 electron volts of energy are liberated. When no electronic rearrangements are involved in the processes, the energy changes are much smaller. Thus, the spacing between the vibrational energy values of molecules is usually of the order of a tenth of an electron volt or less. The energy values corresponding to different states of rotation lie even closer together, the spacing being usually less than a ten-thousandth of an electron volt.

The processes which occur in nature can be roughly divided into those which involve the electrons revolving around atomic nuclei and those which involve changes in the nuclei. All optical and chemical processes and most other known phenomena are electronic in nature. These processes can be more or less readily influenced by varying the temperature, the pressure, or other experimental conditions. On the other hand, the radioactive phenomena, which were discovered and studied by Becquerel, the Curies, Rutherford, and others, are associated with processes going on inside the nuclei of the heaviest atoms. For a long time all attempts at influencing or controlling these processes were of no avail. The reason for this, as well as for the failure of the alchemists, is that atomic nuclei are vastly more stable than the electronic structures surrounding them. To disturb or break up a nucleus the most violent means are required.

The first to succeed in changing the nucleus of an atom was Rutherford, who in 1919 bombarded nitrogen with α-particles and changed it into oxygen and hydrogen. More recently, especially after the invention of the cyclotron and other devices for producing streams of hydrogen, deuterium, or helium nuclei having kinetic energies of several million electron volts, many other artificial transmutations of elements have been accomplished. In many cases it has been possible to measure both the change in mass produced and the energy released in the nuclear reaction, and in all such cases Einstein's principle of the equivalence of mass and energy has been verified.

In 1930 Bothe and Becker in Germany discovered that when beryllium is bombarded with α-particles from polonium some very penetrating rays are emitted. Somewhat later Irène Curie and her husband, Joliot, found that when these new

rays fall on matter containing hydrogen, protons (hydrogen nuclei) are ejected with enormous speeds. Chadwick, in England, repeated these experiments and in 1932 was able to prove that the penetrating rays discovered by Bothe and Becker consist of an entirely new kind of particle which has about the same mass as a proton but no electric change.

The discovery of this new particle, which Chadwick called the neutron, had tremendous consequences. Immediately after Chadwick's discovery it was suggested by Iwanenko and by Heisenberg that all atomic nuclei are built up of neutrons and protons, and this view has received general acceptance.

The extremely large binding energy which holds the neutrons and protons together is a kind of energy never before recognized by man. Heisenberg and Majorana assumed that the peculiar saturation character of the forces between neutrons and protons is connected with a transfer of the charge and the spin from the proton to the neutron and back again. Thus, each particle is assumed to be alternatingly proton and neutron, or the proton and the neutron are regarded as two different states of a single elementary particle, sometimes called the nucleon.

The Japanese physicist Yukawa conceived of a different kind of transformation of a proton into a neutron and predicted that a new kind of particle, having a mass intermediate between the mass of an electron and that of a proton, should be ejected in the process. Such a particle, the so-called mesotron, was shortly afterwards found in cosmic rays. According to Yukawa, it is related to the field of nucleons in much the same way as the light quantum, or photon, is related to the electromagnetic field.

In 1934 Fermi, then in Italy, reported a series of experiments in which a large number of the chemical elements were bombarded with neutrons. Since a neutron has no electric charge, it is not repelled by an atomic nucleus and hence can pass right into it, thus forming a new nucleus which usually is radioactive. A large number of such man-made radioactive forms of the common elements are known, and they are beginning to find important uses in chemical and biological research and in medicine.

In the 1930's a large amount of information was obtained about atomic nuclei. In particular, the energies in the various stationary states were determined for a number of nuclei. Whereas the spacing of the lowest *electronic* energy levels of an atom is a few electron volts, the spacing between the lowest *nuclear* energy levels are of the order of one million electron volts. A theory which provides a general understanding of nuclear structure and energy levels was given by Bohr.

In 1939 a remarkable new phenomenon, the so-called fission, was discovered. Fermi and others had bombarded uranium with neutrons and had obtained complicated results which they were unable to explain satisfactorily. Late in 1938 Hahn and Strassmann in Germany identified one of the reaction products as a radioactive form of barium. Lise Meitner and Frisch immediately concluded on the basis of Bohr's theory that the barium must have been produced by a splitting, or *fission*, of the uranium atom in two nearly equal parts. This idea was brought to America by Bohr in January 1939 and shortly after his arrival was verified at Columbia University, at the Carnegie Institution, at the University of California, and at Johns Hopkins, as well as in Copenhagen and Paris.

It was predicted and verified that about two hundred million electron volts

of energy are released when a uranium atom undergoes fission. This can be understood from a consideration of the atomic masses of the various chemical elements. The elements of intermediate atomic mass are the most stable, as shown by the fact that for them the difference between the sum of the masses of the neutrons and protons making up their nuclei and the nuclear mass is greater than for the very light elements and for the very heavy elements. In fact, for elements like barium the mass of the nucleus is about 1 percent less than the sum of the masses of the separated nuclear particles. For uranium, on the other hand, because of the greater effect of the repulsion between the protons within the nucleus, the nuclear mass is only 0.9 percent smaller than the mass of the neutrons and protons separately. Thus, when a uranium nucleus breaks up into two more or less equal fragments, about 0.1 percent of the mass disappears. This is converted into kinetic energy of the fragments. A simple calculation shows that if it were possible to cause all the atoms in one pound of uranium to undergo fission, about ten million kilowatt-hours of energy would be released.

When it was found that two or three neutrons are ejected in the fission process, the question immediately arose whether it might not be possible to produce a self-perpetuating chain of fission processes and thus release this tremendous amount of energy.

It was soon realized that the ordinary form of uranium, of atomic mass 238, would not be suitable for such a chain reaction since it does not undergo fission when bombarded with slow neutrons. It was believed, however, that a chain reaction might be set up in the rare uranium isotope of mass 235. It was suggested also that a new element, now called plutonium, which is formed by neutron bombardment of U–238, might be suitable.

Fermi and other refugees from Hitler's and Mussolini's Europe succeeded in persuading the government to back researches on the production of U–235 and plutonium and on the explosive release of nuclear energy by fission. This work was carried on for some time on a modest scale, but after a nuclear chain reaction had been actually produced by the end of 1942 the project assumed gigantic proportions. Everyone is familiar with the outcome.

SCIENCE ON THE MARCH

WILL BIOLOGICAL WARFARE INCLUDE PLANT DISEASE?

EVEN more diabolical than the atomic bombs promised us for the war of the future are the weapons of biological warfare so vividly portrayed in Sidney Shalett's recent article in *Collier's* (June 15, 1946)—attack with the invisible infectious agents of botulism, plague, rinderpest, and other decimating diseases of man and livestock. Newspaper articles have suggested that the agents of crop disease might be used in similar destructive fashion. Between the positions of the alarmist and the ostrich is a broad middle ground for conjecture on scientific bases. There is as much danger in overrating as in underestimating potential weapons of offense. What can we expect of plant disease as a weapon in this dreaded war of the future?

The agents of disease are manifold but specialized. Each has its particular, favorite, or exclusive targets. In biological warfare there are three targets: *man*—a single species of paramount importance to himself; *livestock*—a very few species of secondary importance in the survival of man; and *crops*—many species, *in toto* of primary importance in man's survival. We may consider the effects of enemy-induced attack on each of these as separate actions.

The attack on man has been admirably discussed by Shalett. Here we have a single species, vulnerable to several dangerous microorganisms and in a position to be mass-infected by virtue of man's congestion in cities, social intercourse, and dependence on easily contaminated infection sources such as water and milk supplies and canned foods. This, combined with the fact that man considers himself the most important biological target, indicates that biological warfare can be most destructively directed against man himself.

Next we have livestock, on which man depends for meat, eggs, milk, animal fats, wool, certain vitamins, and other less essential products. The species involved, the targets, are few; therefore, biological warfare against these targets by dissemination of the agents of rinderpest and other livestock diseases may be expected to be potentially effective. If biological warfare were even partially effective against livestock, a valuable resource that could not be replaced for a number of years would be lost. It is sometimes suggested that since livestock require as much as four pounds of food to produce one pound of meat, it is wasteful to channel carbohydrate and protein foodstuffs through animal bodies in wartime. To hold this as a legitimate argument against the danger of biological warfare aimed at livestock would be to disregard the value of the stock pile of farm animals on hand at the beginning of a war and the fact that some livestock growth and production can be made on grass and other materials that cannot be used as human food, produced on land much of which could not profitably be devoted to crop production.

The third target is the vegetable matter itself—crops. If it were possible, on a sufficiently broad scale, for a warring nation to infest vital crops of its enemy nation with destructive disease, one can conceive that the resultant blow to national economy might be a decisive factor in the outcome of the war. The collapse of Germany in World War I was clearly associated with failure of the potato crops, due largely to destructive outbreaks of the late-blight disease, which could not be effectively controlled

during war years. Recent press articles have suggested that in the event of another war the American wheat crop could be devastated by enemy introduction of foreign races of stem rust. In Peru, for example, there is a rust race, No. 189, which is particularly virulent against many rust-resistant wheats and which, if introduced and established, might conceivably wreak havoc on the millions of acres of rust-resistant American wheat. To what extent is such a possibility a real threat in a war of the future? We can best answer this by a brief analysis of the natural possibilities and limitations in plant-disease introduction.

Where the other targets of biological warfare number one or a few species, scores of species, with many varieties of each, comprise war-vital crops. In many cases the uses of different crop species are interchangeable: man can receive adequate carbohydrate nutrition from wheat, corn, potatoes, and several other crops or edible and technical oils from flax, cotton, corn, soybean, or sunflower. All these staples are annual crops: From one season to the next we can shift large acreages of one of these crops to another, and, granting the inconvenience and some lost efficiency of production in so doing, our agricultural economy is sufficiently versatile to permit substitutions of crops that could, in considerable measure, annul the effects of disaster in some one of them. We are not, as are some other nations, largely dependent on single crops for carbohydrates, oil, fibers, or other industrial products. To be effective, biological warfare directed against American crops would need to be aimed at many crops simultaneously. We are fortunate that corn, our greatest crop and the one with the most varied uses, is least subject, among the cereals, to sudden destructive disease epidemics.

Most of the agents of plant disease are restricted in their attacks to one, or very few, closely related plant species or even to a few varieties within a crop species. The stem and leaf rusts of wheat, oats, rye, barley, corn, and sorghum are all different fungi, each of practical importance on but one of these crops and each subdivided into races, any one of which will attack only certain varieties of the crop; the dreaded potato late-blight fungus is a serious threat only to potato and tomato; and so for most of the thousands of other plant pathogens. This implies that disastrous sabotage of our crops would need to involve introduction and establishment of many different agents of crop disease.

There are exceptions to this rule of crop specialization of parasites. The root-knot nematode, the fungi of damping-off, Texas root rot, Southern wilt, and charcoal rot, the viruses of tobacco and cucumber mosaic and of aster yellows, and the soft-rot bacteria each attack scores or hundreds of plant species. None of these, however, is capable of efficient dissemination by wind, which is a *sine qua non* of rapid occupation of a new area by a plant disease.

Each of the main, war-vital American crops is grown on millions of acres. To make serious inroads on war economy, a total loss of 20 percent of leading crops, a figure not far from present annual yield fluctuations, might be regarded as a conservatively estimated minimum loss. To accomplish this by enemy action would involve either an impossibly large number of malicious individual inoculations, spread over the national acreage, or the introduction, in fewer locations, of diseases which would be freely windborne over the national acreage.

This forces us to fix attention on those plant diseases that are effectively and rapidly disseminated by wind and are sufficiently harmful to have serious economic impact. We can exclude diseases spread by man in seed or propagating stock since these are amenable to our

control. We can exclude those that are poorly or not at all airborne, including soilborne infestations, virus and bacterial diseases, those caused by nematodes, and those due to many fungi which are poorly adapted to extensive aerial dispersal. Crops such as potatoes, grown in widely scattered areas, separated by long distance, mountains, or deserts which interfere with aerial dissemination of disease, would be poor targets for biological warfare. We can exclude many foreign plant diseases which, because of climatic differences or because of natural disease resistance in our crops, could not establish themselves over a wide area in the United States. Also to be excluded are those diseases that are dependent upon certain species of insects for dissemination, unless, as is unlikely, the particular insect involved is present and adapted to the living conditions over the same wide acreages.

This screening process accomplished, we are left with a rather limited assortment of sufficiently destructive plant diseases that might be suitable for biological warfare. Among these the rusts command attention, but work with them is hampered by the fact that they cannot be cultured on laboratory media and therefore cannot be propagated in quantities adequate for widespread introduction under safe, controlled conditions.

Then there is the problem of successfully establishing infestations in new areas. Every plant pathologist knows the difficulties of establishing infection in experimental plots, even with the aid of such devices as artificial watering, moisture tents, and repeated inoculation. It may be several years between seasons in which a disease will naturally take hold and spread at a dangerous rate. Even if dealing with such easily inoculated disease organisms as rust, our hypothetical saboteur would need the benefit of an unusual streak of luck or many trials to produce a successful introduction of his foreign disease on an important crop.

Assuming, however, that he has accomplished this, the chances are likewise low that the new disease will make serious inroads on the national crop within less than five years. A number of foreign plant diseases have been accidentally brought into the United States and become established, but usually the increase of these to a point where they have been serious factors in national crop production has been measured in decades.

The studies of Stakman in Minnesota and comparable data from Newton in Canada have clearly shown that a number of years is required for the build-up of new cereal rust races to practically important concentrations; and the histories of chestnut blight, the Dutch elm disease, potato wart, pine blister rust, and many other introduced diseases all testify to the length of time needed for serious involvement of the suscept crop in the new area.

Atomic warfare has impressed many with the conviction that in the next war the terrors and destructiveness of years of past wars will be compressed into a few weeks. Should this be the case, biological warfare with plant diseases would be far too slow to be decisive. But if, as some believe, the next war can be one of attrition after the first fireworks, or should we be concerned with a decade or more of prewar sabotage, deliberate introduction of foreign plant diseases might be a factor to be reckoned with. In our favor, in this case, would be the fact that this same delay would contribute to the success of plant pathologists in combatting and controlling the new diseases before they reached critically destructive proportions, as has been done many times in the past with accidentally introduced plant diseases.

If we do not subscribe to the view that biological warfare with plant disease is

capable of striking a major body blow, it is still possible that introduction of a number of foreign plant diseases could bedevil American farmers, acting as one of many secondary handicaps in production. The people of Norway and the Netherlands, during the Nazi occupation of those countries, showed us clearly the harassing effect of many minor acts of sabotage, no one of which was crucial but aggregating a total that seriously interfered with the occupation. As one of such factors, deliberately introduced crop disease could well be a harmful part of a program of organized sabotage.

In the foregoing discussion the point of view has been entirely that of danger to the United States from external sources. If one were to analyze the problem from the standpoint of hazards of biological warfare directed at other nations, not all of this discussion would apply—for example, to a country with a single-crop economy or a poorly organized program of plant-disease research and extension work.

An important contribution to American crop production was made by plant-disease scientists in the last war and will be made in the next, should it come to pass. This was not so much defense against attempted sabotage of American crops, if at all, as raising crop production through control of endemic plant diseases or those accidentally introduced —the past and probably future legitimate field of plant pathological research and education.

K. STARR CHESTER

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BOOK REVIEWS

ANNUAL SUBTREASURY OF SCIENCE

Science Year Book of 1946. John D. Ratcliff. xxxv + 245 pp. $2.50. Doubleday & Co., Garden City, N. Y. 1946.

THIS is Mr. Ratcliff's fifth annual roundup of popular science. It includes 28 articles reprinted from various sources (all American) and grouped in 4 sections: Physics and Chemistry, Medicine, Agriculture, Aviation and Other Sciences. According to original publication source the score is as follows: 6 articles from *Collier's;* 5 from *The Saturday Evening Post;* 3 from *Hygeia;* 3 from *Harper's;* and 1 each from *Time, Business Week, Fortune, Argosy, American Magazine, Life, Farm Journal, Country Gentleman, Country Book Magazine,* John O'Neill's book *Almighty Atom,* and Roy Chapman Andrews' book *Meet Your Ancestors.* Four of them have appeared also in *Reader's Digest.* These statistics help to place the book so far as reader level is concerned. Also they indicate, I think, that science has attained a certain journalistic ubiquity. Whereas there used to be only two inescapables, Death and Taxes, there now are Death, Taxes, and Science.

Most of the articles are written by science writers rather than by scientists. For those who may be curious as to the varied contents of this self-jacket-styled "now-it-can-be-told record of scientific progress during the war years," the following catalogue may suffice: Atomic power (3 chapters), radar, the audion tube, radio telephones, wood and its new uses in the chemical industry, amino acids, textiles from chicken feathers, heat from cold, streptomycin, heart disease, cancer, victory over airborne germs, Rh factor in blood, surgery for otosclerosis, psychosomatic medicine, chemical weed killers, tailor-made livestock (thyroid

studies), hormones for vegetables, kudzu, DDT, rocket passenger ships, wind tunnels, long-range weather forecasting, Alaska the world's hunting ground for prehistoric animals, and finally Dr. Andrews' prognostications on the far future of *Homo sapiens.*

From this it may be surmised that by science Mr. Ratcliff means applied science. Applied science, of course, rides in the caboose and trails, sometimes at some distance, the vanguard of Science with a capital S. Which is to say that by the time a piece of new knowledge resulting from original scientific research reaches *The Saturday Evening Post* or *Collier's* it is no longer new. By that time it has been blueprinted, patented, cultivated, peat-mossed, and subtreasured by the gadgeteers. Already it has probably been applied toward the betterment of mankind, in order, for instance, that doors may open automatically before him, that he may be rocketed to the moon or blown to infinitesimal atoms, that he may perhaps live a few years longer, or that he may talk to his aged mother-in-law in Kokomo, Ind., without getting out of his easy chair. I am in no way averse to the amelioration of mankind, but I should like somehow to see him gloriously educated to the primary fact that the only genuine science is pure science and that pure science rather than spectacular spurts of "scientific development" lies at the roots of medicine, engineering, aviation, agriculture, and a hundred other practices. Neither should any new knowledge be subordinated or arbitrarily relegated to rank: there is no hierarchy of science. That is why it appears to me that such a statement as the following (from Mr. Ratcliff's introduction) is presumptuous: "Galileo, gazing through his crude telescope into the wonders of the night sky, Newton working out his laws of gravitational pull, Einstein threading his way through his unified field equations became poor primitives the day man became superman" [i.e., the day he harnessed the atom]. Why did they become poor primitives? Why did they not become gods?

Mr. Ratcliff's anthology does, however, make interesting and often exciting reading, although he employs one practice that seems to be indefensible. That is the editing of reprinted material without indicating where matter has been deleted or editorial changes made. If an article is not written well enough to be used unchanged (except perhaps for indicated bodily omissions), is it good enough to be reprinted at all? Such editing may not have been done throughout the book, but it was done in the one chapter I had occasion to check, i.e., the excerpt from Dr. Andrews' *Meet Your Ancestors.* An editor has no right to tamper with a man's published writing, be it good or bad. It is as if I should here quote Horace as saying *Nescit vox missa redacti,* whereas he actually wrote *Nescit vox missa reverti.*

PAUL H. OEHSER
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TELESCOPES AND THE MEN WHO USE THEM

Men, Mirrors, and Stars. G. Edward Pendray. x + 335 pp. Illus. $3.00. Harper and Bros. New York. 1946.

LIKE other sciences, astronomy made important contributions to the war when it loaned its practitioners for more destructive tasks than those on which they were normally engaged. Some astronomers were connected with navigation, which is an astronomical problem. Others applied their knowledge of the movements of the heavenly bodies to work in ballistics, calculating the paths of the temporary satellites of our planet which are fired from large guns. Some studied the sun in order to give forecasts on radio propagation. Others were engaged

in problems seemingly far removed from the heavens. For example, methods of preparing and using "window," the thin strips of aluminum foil which were dropped by the ton over Germany and effectively countered the enemy's radar, were largely devised by two distinguished astronomers.

But now the astronomers are back at their telescopes and measuring engines. Work on the 200-inch telescope at Mount Palomar, suspended during the war, has been resumed, and by the end of 1947 this giant instrument will be scanning the sky. The small but powerful Schmidt camera is coming into increasing use, and new techniques, some aided by war researches, are giving greater knowledge of the sun, even permitting us to see the solar corona without waiting for an eclipse.

Thus, the appearance of a new and revised edition of *Men, Mirrors, and Stars* is quite timely. When the first edition was published in 1935—a history of astronomy from the viewpoint of the men who used the telescopes—the book filled a place not otherwise occupied. It was revised in 1939, and now we have the third edition. Unfortunately, there is still no mention of David Rittenhouse, who built the first real observatory on American soil in Philadelphia by 1783. Nor is any credit given to Simon Marius, the German astronomer who used a telescope in 1609, several months prior to Galileo.

Among the new material which has been added is an up-to-date account of the 200-inch telescope and a chapter on the Schmidt telescope and the coronagraph. The list of the world's largest telescopes and the principal American (North and South) observatories, which gives their equipment, lines of research, and personnel, has been revised. Less extensive changes have been made in other chapters.

Men, Mirrors, and Stars is still the best book of its kind. Supplemented with one of the several excellent texts on astronomy, it will give the reader a good idea of how the astronomer works and what his labor reveals.

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AN AMERICAN PHYSICIAN IN CHINA

Doctors East, Doctors West. Edward H. Hume. 278 pp. Illus. $3.00. W. W. Norton & Co. New York. 1946.

CHINA is many things, subtle, complex, multidimensional, confused, and confusing to most Western minds. We are too prone to think of China as a modern state, torn it is true by internal strife, but superficially fairly uniform in culture and education, for we have read much of the dramatic and wondrous change from feudal illiteracy to literate democracy. But it isn't as simple as that. China, like an individual, is today what she is partly because of the effects of her many yesterdays. The past may be forgotten or ignored, but it nevertheless conditions the present. The recent tumultuous yesterdays before and during China's revolution profoundly influence modern Chinese thinking. Thus, Dr. Hume's delightfully whimsical and charming autobiography of his years as a medical missionary deep in the heart of China is excellent background reading for those interested in the human side of the Orient. Dr. Hume writes not of politics or economics or education or health as impersonal disciplines of thought; he writes of the personalities, prejudices, strengths, and weaknesses of the Chinese people as observed first hand in the quarter century from 1902 to 1926. As a state is but the composite of the people, one gains much insight into the present chaos.

Dr. Hume's narrative is surprisingly

and gratifyingly free of the taint of sanctimoniousness. His efforts to understand the Chinese as individuals and not only as a people were sincere and productive. He leads us to a growing respect for the Chinese classics and for the veneration of ancient authority. Above all, he demonstrates that the practice of medicine must ever remain an art no matter what level of understanding the science of medicine attains. Of scientific medicine there is little. Nor is there aught but bare mention of the now known value of some of the ancient Chinese drugs such as, for example, modern ephedrine.

The volume is illustrated with very adequate photographs. The printing is rather better than in many modern books, for the publishers have obviously taken special pains with this, their annual Norton Award prize winner. Particularly delightful are the Chinese proverbs with which Dr. Hume opens his chapters. To those of us concerned with the advancement of scientific thinking I would quote:

> If you plant for a year, plant grain
> If you plant for ten years, plant trees
> If you plant for a hundred years, plant men.

The book is worth reading.

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THE ENGINEER: SCIENTIST OR ENTREPRENEUR?

The Engineer in Society. John Mills. xix + 196 pp. $2.50. D. Van Nostrand Co., Inc., New York. 1946.

IT IS to be hoped that not too many readers will be misled by the title of this book, as was this reviewer, into hoping that it deals with a far larger subject than is in fact the case.

Part of one's disappointment arises from the author's very limited conception of what an engineer is. Following the terminology of the Bell Laboratories, the author is willing to accord the designation "engineer" only to a comparatively small group of men closely akin to researchers in pure science, though the book is more than halfway along before he explicitly says so, in the following words:

> This group of engineers and scientists . . . divides by aptitudes, and to a large extent by positions, into three classes: (1) those creatively concerned who carry on research, development and design; (2) those who select and apply to practical problems the products of the first class, like most of the engineers in public utility companies or those of manufacturing concerns; and (3) those who by aptitude and ability have progressed beyond their fellows of the first two classes into positions of management or business. . . . Most of this book has been concerned with those of the first class. . . . For purposes of this summary, and any conclusion it permits, the second class is included but the third class strictly excluded. The third class is at present necessary to society and warrants respect but it should not be included in a discussion of the engineer in society because its attitudes are inherently those of the controllers of industry, of managers, entrepreneurs, and exploiters.

It might be mentioned in passing that the above includes almost the only phrases complimentary to executives—even those in research organizations—in the whole book. Elsewhere, when executives are mentioned at all, it is usually in ways such as this:

> The production of executives is a necessity in any large organization. They must be formed, but should they be fabricated from such high priority material as research scientists represent?

This conception of an engineer is of too limited scope to justify the book's title. There are a lot of other kinds of engineers in the world besides research and development men. Indeed management is rapidly becoming not only a branch of engineering but, at least numerically speaking, its most important branch. Something like two-thirds of the graduates of the engineering schools of the United States soon find themselves working in some phase, even if a humble one, of the great field of management.

Many of us, therefore, resent the pre-empting of the word engineer by any limited group within the profession. We feel that the really important question which the title of this book suggests, but its author ignores, is the part which all these technically trained men are, by virtue of their training, specially fitted to play in molding the society of today and tomorrow into something even finer than can now be foreseen. Furthermore, in playing this important part, it doubtless will be precisely those engineers with executive responsibility who will have the greatest influence.

The author's small group of "engineers" may, however, be important enough to be written about, and at, as a separate group, preferably under a more appropriate title. It may even be true that, as the author says, although

> unfortunately in most cases their objectivity is limited to matters of physical science and does not extend to those of religion and psychology, politics, and economics . . . nevertheless, the fact that they are accustomed to apply the scientific method, and hence *might* [italics mine] extend it to those matters which so vitally affect our society, constitutes the only hope [the author sees] for the future.

Even then the book is a disappointing sequel to its stimulating introduction. True, three whole chapters, about a fifth of the book, are separated out in the table of contents as "A Course for Action." The gist of them is, however, only in the third of them called "Organizing for Evolution." Its first sentence is, "Scientific workers in industry should organize, I believe, for their own protection and advancement but even more for the greater social service which that will permit." A little further on this "course for action" is further elaborated:

> The immediate problem before engineers and scientists in industry is an engineering study of their class relationship to society. The first aspect of that problem is the scheme under which they receive their rewards, in other words, their pay. That is the subject which I propose for their scientific investigation. Like most research projects, as the investigation progresses, it will disclose new problems. I shall miss my guess, on the basis of other projects observed, if it does not very soon indicate a broad series of studies which will bring the engineer and scientist into fruitful contact with the major problems of our time. If the project is attacked in the objective manner of the scientific method it should lead to socially important results.

This is a definite suggestion. But if such an organization were formed, whether union-affiliated or not, this reviewer would miss his guess, on the basis of other projects observed, if it ever got far beyond its first object of study, namely, pay. The currently crystallizing groups of atomic scientists, whose activities stem from public-spirited motives in no way related to pay, seem to this reviewer to be far more hopeful signs that we are approaching a future in which scientists will be socially as well as technically useful.

Nevertheless, John Mills has written an interesting and provocative book, even if its great value has little connection with its title. Its obiter dicta, stemming from a wisdom ripened by ten years in university teaching and thirty-five years as an "engineer" in the Bell Laboratories, range from how to overcome insomnia and why women fail in technical (though not in biological) research to how to select promising young employees and how to make friends and influence people with the written word. His own writing is trenchant and, at times, exciting. He is a delightful philosopher rambling at will over the whole universe of the Bell Laboratories. If a reader does not expect what isn't there, as this reviewer did, he will find something stimulating on every page and, if he takes the trouble to digest it all, he will be a better man forever after.

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HOBOKEN, N. J.

COMMENTS AND CRITICISMS

Oregon's Wonderland of the Past—The John Day

For several months I planned for this summer a trip that was to include the John Day River in Oregon. I have been interested in that area because of the gold mining days and a very pleasant journey the family took several years ago up the Deschutes River from Crater Lake. When the article by Dr. Stock appeared in the July issue of THE SCIENTIFIC MONTHLY, I was naturally very much pleased.

We took the trip. We spent a night on the gravel of Canyon Creek, gravel that was all worked over by the miners about the time of the Civil War. We saw the skull of the first man hanged in Canyon City, the skull of the second man, and many other relics of the early days, which were pretty wild.

The next day we followed the river from John Day on down to Twickenham. The Picture Gorge is well worth a trip in itself. The area is a very fine cattle country. The article by Dr. Stock was an excellent geologic guidebook.

I enjoy reading THE SCIENTIFIC MONTHLY. My own additions to the field of knowledge are practically nothing at all. My main interest, of course, is in the field of education. Seattle schools do give more emphasis to science than the recommendations of the Educational Policies Commission propose. We are trying to teach them all to appreciate this world and to think straight.—EDGAR A. STANTON.

Science and Incentives In Russia

I wish you would try to induce the *Reader's Digest* to reprint Dr. Langmuir's article in your August issue. That would enlighten the folks, since he can hardly be accused of being a fellow-traveler.

I had the good fortune to attend a lecture by Professor James W. McBain, of Stanford, given shortly after his return from the Russian trip, but I do not believe his talk was published.

Dr. Langmuir relates that a man in a good position may get as much as five times more food ration points than the ordinary mortal and comments that if a college professor or the president of a company in this country received more red points than a factory worker, there would be protests. I think he is right, but the point is that we cannot do these things directly but can and do by indirection. The president of a company could eat his fill three times a day at any restaurant, while the factory worker couldn't afford to do that. I guess this is the kind of comparison that foreigners classify as Anglo-Saxon hypocrisy.

I have been told that in England during the war the guests eating out had to produce their ration cards. That is as it should have been, and it would have discouraged the black market. —B. F. JAKOBSEN.

Immortality

This letter has two objectives:

(1) To congratulate and thank you for the very marked improvement in the MONTHLY. At one time I was strongly tempted to send in a protest against the very poor quality of many of the articles, when it occurred to me that a very large number of people who are able to write interesting and instructive articles were engaged in important war work with no time for such writing; therefore I desisted and am now mighty glad I did. The August number of the MONTHLY has much of interest for me.

(2) I should like to ask if it is not about time for you to announce that "this is positively the last word" on the immortality of the soul. I have yet to read a single article on this subject, either in the MONTHLY or elsewhere, that by the most elastic stretch of the imagination could be called scientific. The recent articles on the subject in the MONTHLY sound more like outpourings of argumentative children than the sober thoughts of real scientists. When any person has a sufficient number of well-established facts to form a reasonable conclusion on this subject, I am willing to read him, or listen to him, giving him full credit for any superior scientific qualities he may show; in the meantime, I consider that the space in my number of the MONTHLY devoted to that question could much more profitably be devoted to other subjects.—C. E. HORNE.

The Educational Policies Commission Banishes Science

It seems to me that Franklin Bobbitt [August issue] has made a most important point and one that I would like to have read by some of our superintendents and school board members out in these parts.

Incidentally, I want to again commend your entire program of encouraging our men of science to take a more active and effective part in the civic life of our nation. You have been hitting the nail squarely on the head for the

past year in pointing out how badly aloof so many of our scientific men have been and the importance of their taking an active part therein if our distinctively American type of free civilization is to continue.—J. W. CLISE.

Our Everyday Reckonings

I have been reading in the August issue the tirade of Engineer George Wetmore Colles against the metric system. Mr. Colles evidently needs someone to tell him that, according to at least one authority (G. W. Colles, SM 63, 2, 1946), "an article on the metric system, either pro or con, is by this time something worse than 'old stuff.' "

Mr. Colles expresses surprise that lawmakers would even consider the metric system. I have been told that our Founding Fathers threw over the English monetary system and actually originated a decimal system of their own.—OWENS HAND BROWNE.

On the Mathematics of Committees, Boards, and Panels

It was with amazement that the writer studied the recent [August 1946] article by Mr. Bruce S. Old in THE SCIENTIFIC MONTHLY.

Undoubtedly Mr. Old has made a valuable contribution to this abstruse branch of mathematics and deserves only the highest praise for the scholarly way in which he applies the results to practical problems. Nevertheless, one is at a loss to understand how he can have imagined that the only object of a committee is to maximize the various expressions involving ComBulPac. Granted that this usually reaches a maximum, there are cases where a minimax is sought. In such cases, the committee strives to mini-maximize its functions. This is done most successfully by prefacing the answer to any question by the Chairman by the words, "Yes, and No." What could be more simple?—JEROME FEE, Chairman, American Chairman's Association.

Tute's Philosophy

The letter from Sir Richard Tute (SM, October, 1946) contains a statement that greatly interested me, namely: "Just as every man recognizes that other men exist with personalities akin to his own, so may he recognize that every entity that exists may in its real aspect be a personality." Tute traces this philosophy —"that the whole universe is a plenum of life, mentality, or personalities"—back to Liebnitz, yet it seems to possess an origin which is certainly more primitive and probably of far greater antiquity. The Amerind, for example, believed that everything possessed its own form of life. One had only to recite the proper formula, and the slothful stone could be made to move, to live, and often to obey the will of the magician.

Tute seems to recognize the primitive character of his deduction by stating that "every religion . . . springs from intuitive knowledge of the spiritual quality of all existence." To the scientifically uncautious the faith of the Amerind may seem marvelously prescient of Tute and of the atomic bomb, but a small familiarity with the subject reveals total lack of relationship. The simple, mystical chants recorded in the Swimmer Manuscript of Cherokee sacred formulas, for example, are not the forerunners of the Manhattan Project. Similarly, the easy syllogism, the far-flung philosophy, must remain suspect if we are to retain any vestige of the scientific spirit which first flowered in ancient Greece only to be destroyed by the Neo-Platonic philosophy of medieval Christianity. Somehow, one seems to detect similarities between Tute and the Plato of the Thomists.

I am not a materialist for I am not certain that the nature of matter explains everything. Yet I am a "Darwinian biologist," for the facts of the *Origin of Species*, plus the overwhelming mass of facts added by later evolutionists, make the theory of biological advance through the operation of several factors, including natural selection, as near a sure thing as is scientifically possible. No easy syllogism, no far-flung deduction from recent physical theory, negates the titanic labors of Darwin, of Nobel Laureate Thomas Hunt Morgan, and of many, many others.

Darwin indicated that natural selection alone was not sufficient to explain the origin of species. Subsequent researches have abundantly confirmed this view. Strangely, at each tiny addition to Darwin's theory—additions which detract nothing but add further support —some scientific popularizer—too often a scientist himself—has cried that Darwinism is dead, and the philosophers use that cry to embarrass all biologists.

To believe in the existence of matter and of energy is not to deny the existence of the personality, although some definitions of this latter reality seem overextended. Tute seems to tell us that all matter may be converted to energy by appropriate techniques; therefore, matter does not exist. Similarly, the sentient being called Sir Richard Tute may be converted to a corpse by techniques used altogether too frequently of late; therefore, Tute goes the way of matter, of materialism, and of mechanism. Before he "sinks without a trace," I hope he will reveal to us the system of plumbing in his dwelling that he can be so unaware of all mechanisms.

The little poem on "Atomic Power" was a masterpiece. I hope we hear from King again. —PAUL D. HARWOOD.

Science and the Pursuit of Values

In critical comment on "Science and the Pursuit of Values," permit, if you will, the query as to what has become of *justice* as a "value." Why is this so glibly ignored in defining morality as that "which originates as an automatic yielding to the dictates of conscience" and which "asks for principles of behavior and demands proof of the freedom of the will"? Why does the author evade the problems of institutional economics and politics in their relation to science? Why does a philosopher who moves so easily into nebulous, hedonistic definitions of "value" as a way of eliding the problem of conflict between science and "religion," find it so difficult, despite the sweep of "values" which he ascribes to "science," to bring the problems of justice within its otherwise pretentious purview that they are not even mentioned? Can it be possible that there is a discipline that is excluded from the syntheses of philosophy?—ALDEN A. POTTER.

Mr. Potter's criticism of my article on "Science and the Pursuit of Values" indicates a failure to grasp the purpose and intent of my discussion. There are two things which I did not do in this article, since I felt that they were not pertinent to the development of my thesis. First, I did not consider *all* the major human values. In addition to beauty, piety, and moral goodness, which I discussed in some detail, I mentioned but did not elaborate upon health, wealth, love, and values of play. This list makes no pretense to exhaustiveness. Second, I did not discuss all the *specific subvalues* which make up the major values. Justice, honesty, and the regard for others are subvalues under moral goodness. My aim was merely to show that if we select certain typical value pursuits, such as art, religion, and morality, and examine their features, we are able to conclude that science is in many respects a similar enterprise.—A. CORNELIUS BENJAMIN.

A Loyal Reader

Probably your correspondent is one of your oldest and longest time subscribers and devoted readers; for I have [the last week in September] passed my eighty-sixth birthday and have taken, read, and passed around among friends not financially overburdened, every number of THE SCIENTIFIC MONTHLY and older publications from your presses. Always I have advised: "Read and pass on."

Born with progressive myopia, I graduated from public school, town of Flatlands, L. I., Erasmus Hall, Flatbush, L. I., Rutgers College, '83, Union Theological Seminary, '86, and Columbia University, '92. I served continuous pastorates, with nine years of teaching in Hope College, Holland, Mich., and four years in the Northwestern Bible and Missionary Seminary in Minneapolis. In both reading and teaching Greek, my vision gradually has faded. Your correspondent sees today "as in a glass darkly."

When my present subscription will have expired, I do not expect to renew it. My good wife has good eyesight, reads the newspaper and all my letters (well, perhaps not quite all for I use a black, slit piece of glass and a pocket pencil light, and so preach and lecture). My health is abundant, Bless God! Your SCIENTIFIC MONTHLY has been a good instructor, and I desire to express my hearty thanks, fraternally, for true God-created Science.—JOHN TALLMADGE BERGEN.

The Last Canute

Please accept my congratulations on Mr. Hardin's article "The Last Canute." It is the most refreshing breeze to blow our way for a generation. I have made it required reading for the entire staff.—HAROLD LANCOUR, Librarian.

Thanks for having printed Garrett Hardin's article "The Last Canute." By his good-humored approach he has made a point very forcibly.

I have written him jocosely, sending him the following table of figures and remarking that if the New Alexandrine Library Fund had been a reality this library would be in a good position to go after some of the money.

Statistics of the Bangor (Maine) Public Library:

Year	*Added*	*Withdrawn*	*Net Additions*
1945	8,861	3,267	5,594
1944	9,950	7,218	2,732
1943	9,521	3,534	5,987
1942	7,859	3,791	4,068
1941	9,200	3,212	5,988
1940	11,520	4,255	7,265
1939	13,200	3,998	9,202
1938	13,465	4,653	8,812
1937	12,215	5,698	6,517
1936	10,880	4,645	6,235

—L. FELIX RANLETT, Librarian.

THE BROWNSTONE TOWER

In a few weeks scientists of all kinds will begin to assemble in Boston for the 113th Meeting of the A.A.A.S. Those who, like the editor, regarded "the Christmas meetings" as an annual event before the war and attended them regularly will welcome their return. Such old-timers like to recall the events of past meetings, and usually it is not a scientific development that sticks in the mind and marks a meeting but rather some extension of the Christmas spirit among friends—a conversation, a place visited, a gay dinner, or a long walk. Sometimes memory of the weather during a meeting predominates, especially when the visitor was unprepared for the conditions encountered. So it is that I remember the Des Moines Meeting of 1929 for its unseasonable but delightful warmth and the Boston Meeting of 1933 for its bitter, penetrating cold, which was most unusual for that region. The temperature dropped to a record low of $-18°$ F. Snow had fallen, and the frigid wind lashed our faces as we plowed like arctic explorers between our Boston hotels and the Harvard campus where the sessions were held. That experience led at least one society to hold its winter sessions thereafter in the meeting rooms of its own hotel, and at the forthcoming meetings in Boston no chances will be taken by most societies and sections. They will meet in their hotels.

The universities of Boston and Cambridge have grown markedly since I was a graduate student at Harvard in 1924–26, and many changes have occurred since the previous Boston meeting of 1933. One change, little noticed and regretted only by the few who worked at Harvard's Bussey Institution, took place when the great Biological Laboratories of the University were built and occupied. Then the Bussey Institution was abandoned as a center of research in entomology, genetics, and plant anatomy. The old Bussey was a forbidding, monastic stone building overlooking the grounds of Harvard's Arnold Arboretum in Forest Hills, Boston. No students devoted to research were more fortunate than those who studied at the Bussey. There they had room to work in a quiet and secluded environment conducive to thought. Great scholars—Wheeler, Brues, East, Castle, and Bailey—were busy with their own research and writing but were available for consultation. They never intruded upon the work of their students, nor did their students lean heavily on them. All worked independently in zealous research undisturbed by commercial or military considerations. The Bussey was indeed an ideal temple of science, the like of which we may not see again in these days of research for a purpose.

Another aspect of Boston, about which I was then unconcerned, was recently brought to my attention by the publication of *The Happy Profession,* by Ellery Sedgwick, for many years editor of Boston's *Atlantic Monthly.* As I have privately regarded the SM as the *Atlantic Monthly* of science, I look up to Sedgwick as a master from whom I can learn and consequently I read his book with avidity. Those who want to know why he called magazine editing "the happy profession" should read his book also. From my own experience I can say that Sedgwick is right—the satisfactions of an editor come from his human contacts, which are likely to be more numerous and varied and stimulating than those enjoyed by workers in other professions. Even those who revile the editor and deplore his judgment add to the richness of his life. And so, as Christmas and the Boston Meeting approach, may I express the hope to all who have met me or written to me that the coming Christmas season will be "just like *old* times"—good friends, good talk, good food, good weather!

F. L. Campbell

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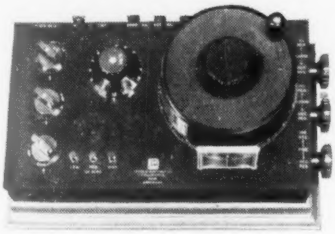

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THE SCIENTIFIC MONTHLY

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Contents

MEET THE AUTHORS

FLORENCE W. VAN STRATEN, Ph.D., is an Aerological Engineer with the U. S. Navy in Washington, D. C. She was born in Darien, Conn., in 1913 but has lived most of her life in New York City and Washington. She received her degrees in chemistry at New York University. After holding a teaching fellowship, she was made a regular faculty member of Washington Square College, N.Y.U. At that time she specialized in the physical chemistry of metals, alloys, and metallic reactions. In 1942 she became an ensign in the U. S. Naval Reserve and was assigned to the Massachusetts Institute of Technology for a course in aerological engineering. Thereafter she was sent as Naval Liaison Officer to the Daniel Guggenheim Airship Institute and then was ordered to the Office of the Chief of Naval Operations in Washington where she conducted research in Operational Analysis and subsequently in the Research and Developments Section.

F. R. FOSBERG, Ph.D., is a roving botanist, who was born in Spokane, Wash., in 1908. His early interest in natural science flowered at Pomona College where he decided to become a systematic botanist. His first job as curator of the herbarium at the Los Angeles Museum was abolished by depression economies. He then accepted an assistantship at the University of Hawaii where he spent five years, including six months on the Mangarevan Expedition of the B. P. Bishop Museum. He emerged with an M.S. and a permanent interest in the flora and geography of the Pacific Islands. He took his Ph.D. at the University of Pennsylvania in 1939. Connected with the USDA and FEA during the war, he went to the Colombián Andes in 1942 to explore for stands of wild Cinchona (quinine). His work on Cinchona continued until this summer when he was sent on a six months' botanical survey of Micronesia. Next year, as a Guggenheim Fellow, he will study the genus *Cinchona*.

MEET THE AUTHORS, Continued

SAMUEL A. STOUFFER, Ph.D., LL.D., Professor of Sociology and Director of the Laboratory of Social Relations, Harvard University, is chairman of a joint committee of the National Research Council and Social Science Research Council on the measurement of attitudes, opinions, and consumer wants. Born in Sac City, Iowa, June 6, 1900, he has an A.B. and LL.D. from Morningside College, an A.M. from Harvard, and a Ph.D. from the University of Chicago. He spent a year at the University of London in postdoctoral study. Dr. Stouffer taught sociology at the University of Wisconsin from 1930 to 1935 and was Professor of Sociology at The University of Chicago, 1935 to 1946. His specialty is the application of quantitative methods in social science. During the war he was chief of the professional staff in the Research Branch, Information and Education Division, War Department (on leave from The University of Chicago).

ARTHUR H. COMPTON, Ph.D., LL.D., L.H.D., is Chancellor of Washington University, St. Louis. Pages would be needed to describe the career of this great physicist and public-spirited citizen, to whom have come all the honors and world-wide recognition that a scientist can attain, topped by the Nobel Prize and the presidency of the A.A.A.S. We shall therefore only remind the reader that Dr. Compton was born in Wooster, Ohio, September 10, 1892, that he graduated from the College of Wooster and took his graduate work at Princeton, and that his great reputation was established while he was Professor of Physics at the University of Chicago from 1923 to 1945. Dr. Compton is known for his work on corpuscular and wave properties of X-rays; on the earth's rotation; on atomic structure; and particularly for his world survey of cosmic rays. His war service as Director of the Metallurgical Laboratory of the University of Chicago links him with the development of the atomic bomb.

MEET THE AUTHORS, Continued

STANKO MIHOLIĆ, Ph.D., is a Croatian chemist, born in 1891. He took his doctorate at the University of Zagreb in 1918. In 1928 he worked for some time under the famous biochemist, F. G. Hopkins, at Cambridge, England. In 1930 he became chief of the Chemical Department of the Central Institute of Hygiene in Belgrade and in 1936 Assistant Professor in the Medical Faculty of the University of Belgrade. During all this time Dr. Miholić was studying the chemical composition of mineral waters. As his work led to a new geochemical method for ore prospecting, he was called back to Zagreb in 1939 to organize a chemical laboratory for the Department of Mines of Croatia. He became Director of this laboratory, called the Institute for Fuels, Minerals and Metallurgy, which became a department of the Institute for Industrial Research in 1945. As an avocation Dr. Miholić has long been interested in art chemistry and has lectured in Belgrade.

J. RUD NIELSEN, Ph.D., is Research Professor of Physics at the University of Oklahoma. He was born in Copenhagen, Denmark, in 1894. After finishing his training in physics at the University of Copenhagen, he was instructor at the Royal Technical College for three years. In 1922 he came to the United States as a fellow of the Scandinavian-American Foundation. He took his doctorate at the California Institute of Technology in 1924 and joined the faculty of the University of Oklahoma in the same year. During 1931–33 Professor Nielsen worked in the Institute of Theoretical Physics at Copenhagen, the first year as a fellow of the Guggenheim Memorial Foundation. Dr. Nielsen's researches have been mainly in Raman and infrared spectroscopy. During the war he applied spectroscopic methods to the solution of problems connected with the production of synthetic rubber and aviation gasoline.

MEET THE AUTHORS, Continued

T. V. SMITH, Ph.D., D.Litt., LL.D., is Professor of (Political) Philosophy at The University of Chicago. From his base at the University he has ranged far and wide into the contemporary life of this country, making his influence felt among scholars and laymen alike. Professor Smith was born in Blanket, Tex., in 1890. He graduated from the University of Texas and took his M.A. there, going on to the University of Chicago for his Ph.D., where he became Professor of Philosophy in 1927. As a political scientist he has practiced politics; first as an Illinois State Senator (1935–38), then as Congressman at large, representing Illinois in Washington (1939–41). He was the author and first chairman of the Legislative Council of Illinois and Chairman of the Board of the Council of State Governments of the United States. He has taken a great interest in education by radio. He was a founder of The University of Chicago Round Table and a participant in such programs as the "Town Hall Meeting of the Air" and "Information Please." He took part in a series of radio debates with Senator Robert A. Taft. Professor Smith is the author of more than a dozen volumes on philosophy and politics and collaborated with Senator Taft in writing *Foundations for Democracy*. He edits the *International Journal of Ethics* and *State Government*. During the war Dr. Smith served on the educational front: Director of Education for the Allied Control Commission, Sicily and Italy; laid foundations in London for Allied renovation of German education; Military Government instructor for Japan; Head, American History, Administrative School for German Prisoners, Ft. Getty; and Trainer of German Prisoners in democracy, Ft. Eustis, Va. This year he was a member of General MacArthur's Educational Mission to Japan. Dr. Smith has published previously in the SM: "Bases of Bryanism," 1923, and "Democratic Leadership," 1925. In the September 1946 issue of the SM we published a sample of his verse.

CHARLES F. MULLETT, a historian, JOHN G. SINCLAIR, an anatomist, and ALEXANDER F. SKUTCH, a naturalist, are repeaters. See SM, December, September, and April 1944, respectively.

Highlights of the 1946 International Science Exhibition

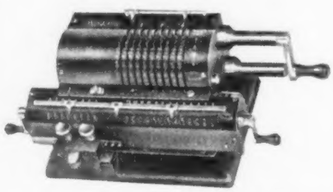
Each year in conjunction with the Annual Meeting of the A.A.A.S. the Association sponsors a Science Exhibition. This year the scope of the exhibition has been considerably enlarged by the inclusion of exhibits from overseas and from organizations heretofore not represented. There are two principal types of exhibits: Technical exhibits are supplied by manufacturers of scientific equipment and apparatus, by publishers of scientific and technical books, and by laboratory supply houses; scientific exhibits are arranged for by university and college research personnel, by foundations for research, and in some cases by affiliated societies. Complete descriptions of each exhibit will appear in the December 6 issue of SCIENCE and in the general program to be distributed at the Boston meetings. The scientific exhibits of this year's meeting promise to be of unusual interest, not only because of the variety of exhibits but because of their excellence.

Most readers of THE SCIENTIFIC MONTHLY are acquainted with its companion publication of the Association, SCIENCE. A little-known fact about SCIENCE is that it was founded by Thomas A. Edison and published by him for a period of almost two years. He later sold the magazine to Alexander Graham Bell. Since 1947 will be the centennial year of Edison's birth, the Thomas A. Edison Centennial Committee has agreed to display a collection of Edisonia from the Thomas A. Edison Laboratory in West Orange, New Jersey. Another unusual exhibit will be made available through the cooperation of the Brazilian Consulate in New York and Flora Castano Ferreira. This exhibit will contain approximately one hundred original paintings, water color on parchment, made between 1810 and 1831 by Pancrace Bessa for the periodical, *L'Herbier General de L'Amateur*. These paintings will be a substantial portion of the original collection presented by Charles X of France to the Duchess of Berry.

Overseas scientists will be represented by exhibits obtained with the cooperation of the British Commonwealth Scientific Office in Washington. Australia, New Zealand, South Africa, Canada, and the United Kingdom will have exhibits on various phases of scientific research within each of their respective countries.

Our affiliated society, The American Chemical Society, is sponsoring an exhibit on atomic energy. This exhibit is now on display in England and will spend a week at M.I.T. before coming to our exhibition. The Science Clubs of America will show the work this organization does among the high schools of America. Several large panels from the National Foundation for Infantile Paralysis give a very complete story of the research which this organization sponsors throughout the United States. From the Harvard Forest Dr. Stephen H. Spurr and C. T. Brown, Jr., will present a series of maps showing changes in land use and forest composition in the New England states. Included in the exhibit are data on recent research in mapping and in estimating the volume of forests from aerial photographs.

Dr. Robert R. Collins, of Smith College, will show a self-contained instrument for demonstrating optically the simpler geometry of map projections.



The U. S. Department of Agriculture will have an exhibit on White Pine blister rust. The Signal Corps and the Air Weather Service plan to show equipment used for meteorological observations. Additional panels will demonstrate synoptically the integration of data for use by forecasters. The National Roster of Scientific and Specialized Personnel will have a booth for dissemination of information about its services, and personnel will be in attendance to assist scientists in completing their records for the Roster's files.

The Weather Bureau of the Department of Commerce will have an exhibit on radiosonde. The National Bureau of Standards' exhibit will have three divisions: One on ionospheric research, another on optical glass, and a third on the purification of hydrocarbons.

The medical field will be represented by an exhibit sponsored by Dr. Edward L. Prien and Dr. Clifford Frondel. From the Far West Dr. Con Fenning, University of Utah, brings another electronic exhibit demonstrating the use of electronic instruments in medical research involving the presence of foreign bodies. Paul D. Zottu and his colleagues plan to demonstrate electronic drying for moisture determination. Another exhibit on electronic research is being sponsored by the Western Union Telegraph Company in its display on concentrated arc lamp.

Science Library

The Science Library this year presents several innovations. In addition to the regular displays of recent scientific and technical books there will be sections on scientific journals and technical publications, technical papers published in house organs of large industrial manufacturers, and an extensive file of book reviews taken from approximately one hundred scientific journals. The Association has been able to carry forward these improvements because of the assistance of the Technical Library Consultants, of New York City.

Heretofore the December issue of THE SCIENTIFIC MONTHLY has carried a list of the books to be on display at the Science Library. This year's list, however, was much too large for inclusion in the December issue. It is planned, therefore, to publish the library list separately, together with a list of two thousand other scientific books published in the first nine months of 1946. This combined list of books will be distributed at the Science Library. Readers of THE SCIENTIFIC MONTHLY may obtain these lists by writing to the Washington office, 1515 Massachusetts Ave., N.W., Washington 5, D. C.

Books from the following publishing houses will be on display:

Annual Reviews, Inc.
The Blakiston Company
Burgess Publishing Company
Cattell and Company, Inc.
D. Appleton Century Co., Inc.
Chemical Publishing Company
Chronica Botanica Co.
The Commonwealth Fund
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Alfred A. Knopf, Inc.
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Boston, 26-31 December 1946

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Bradford, 275 Tremont St.	3.30 to 3.85	5.00 to 6.00	6.00 to 7.00
Braemore, 464 Commonwealth Avenue	3.50 to 4.40	5.50 to 6.60	6.60 to 7.70
Broadway, 315 Tremont St.	2.50		
Buckminster, 645 Beacon St.	3.00 to 3.50	4.50 to 5.00	6.00
Charlesgate, 535 Beacon St.	3.85 to 4.40	5.50 to 6.60	
Commander (Cambridge), 16 Garden St.	3.30	4.40	5.50 to 6.60
Commonwealth, 86 Bowdoin St.	2.50		4.50
Continental (Cambridge), 25 Garden St.	3.30 to 4.40	5.50	6.60
Copley Plaza, Copley Sq.	4.40 to 7.70	6.60 to 7.70	7.70 to 8.80
Copley Square, 47 Huntington Ave.	2.75 to 3.30	4.40 to 5.50	6.60
Essex, South Station	3.30	4.40	5.50
Fensgate, 534 Beacon St.	4.00 to 5.00	6.00	7.00
Gardner, 199 Mass. Ave.	2.50	4.40 to 5.50	
Kenmore, Kenmore Sq.	3.85 to 4.40	5.50 to 6.60	6.60 to 7.70
Lenox, Exeter St.	3.30	4.40 to 5.50	6.60
Lincolnshire, 20 Charles St.	3.30 to 4.40	5.50 to 6.60	
Manger, North Station	3.00 to 4.40	4.40 to 5.50	6.60
Minerva, 214 Huntington Ave.	2.50 to 3.00	4.00 to 5.00	
Myles Standish, 30 Bay State Rd.	3.30 to 4.40	4.40 to 6.60	6.60 to 7.70
Parker House, 60 School St.	3.85 to 4.40	5.50 to 6.60	6.60 to 7.70
Pioneer (for women), 410 Stuart St.	2.00 to 3.00	4.00 to 5.00	
Puritan, 390 Commonwealth Ave.	3.85	6.60	
Sheraton, 91 Bay State Rd.	3.30 to 4.40	5.50 to 6.60	
Statler, Park Sq.	3.85 to 5.50	5.50 to 7.70	6.60 to 8.80
Touraine, 62 Boylston St.	3.30 to 4.40	4.50 to 5.50	6.60 to 7.70
Vendome, 160 Commonwealth Ave.	3.30 to 4.40	4.40 to 5.50	6.60
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SOCIETY HEADQUARTERS

Boston Meeting, December 26-31, 1946

General Headquarters: The Statler Hotel will serve as the general headquarters of the Association, housing the meetings of the Council and Executive Committee.

Headquarters of the sections of the Association and of the societies meeting with the Association follow:

Statler Hotel: Section on Medical Sciences (N), Subsections on Dentistry (Nd) and Pharmacy (Np); Academy Conference, American Microscopical Society, American Society of Naturalists, American Society of Parasitologists, American Society of Zoologists, Genetics Society of America, Ecological Society of America, Limnological Society of America, National Association of Science Writers, Sigma Delta Epsilon, Society for the Study of Evolution, Society of the Sigma Xi, and American Dietetic Association.

Bradford Hotel: Sections on Anthropology (H), Psychology (I), and Education (Q); American Nature Study Society, National Association of Biology Teachers, National Science Teachers Association, Pi Lambda Theta, Committee on Scientific Policy of the A.A.A.S., Cooperative Committee on Science Teaching of the A.A.A.S., and Society for Research in Child Development.

Commander Hotel: Sections on Astronomy (D) and Geology and Geography (E); American Astronomical Society, American Meteorological Society, and American Geological Society. Meetings of these sections and societies will be held at Harvard University.

Copley Plaza Hotel: Sections on Agriculture (O) and Botanical Sciences (G); American Fern Society, American Society for Horticultural Science, American Society of Plant Physiologists, American Society of Plant Taxonomists, Botanical Society America, Mycological Society of America, Phi Sigma Biological Society, Sullivant Moss Society.

Kenmore Hotel: Sections on Physics (B), Chemistry (C), Social and Economics Sciences (K), History and Philosophy of Science (L), Engineering (M), American Philosophical Association, American Statistical Association, History of Science Society, Institute of Mathematical Statistics, Philosophy of Science Association, and Pi Gamma Mu.

Hotels adjacent to the Bradford are the Avery and Touraine; those adjacent to the Copley Plaza are the Charlesgate, Fensgate, Pioneer (for women), Copley Square, Lenox, and Vendome; those adjacent to the Kenmore are the Puritan, Braemore, Myles Standish, Sheraton, Buckminster, Gardner, and Minerva.

The Lincolnshire, Commonwealth, Bellevue, and Parker House hotels are grouped about the Boston Common and are within convenient walking distance of the Statler and Bradford hotels. The Commander and Continental hotels are adjacent to Harvard University.

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